Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

ENERGY RESEARCH LABORATORIES

ANNUAL REPORT 1984/85

Compiled and edited by J.L. Harcourt

MAY 1985

ENERGY RESEARCH PROGRAM

ENERGY RESEARCH LABORATORIES

DIVISION REPORT ERP/ERL 85-37 (TR)

89-00996/

FOREWORD

A principal objective of CANMET's Energy Research Program is the development of the technologies required to conserve and to increase the supply of liquid fossil fuels in Canada to bridge the gap that exists between domestic supply and demand (both internal demand and export opportunities). The Energy Research Laboratories (ERL) responds to this R&D objective on matters related to the upgrading of oil sands, heavy oil and synthetic crude production; coal combustion; coal gasification and liquefaction; and improved oil and gas domestic heating furnaces. Important input and guidance on project selection and implementation is provided by industry advisory committees and user groups. Shared-cost projects with industry are underway in-house, and major elements are undertaken in the private sector through shared-cost contract R&D programs.

This report summarizes the activities of ERL during fiscal year 1984/85 and is intended as a report to CANMET management and staff and as a working document for preparing the CANMET Review and other branch publications.

For operational purposes the division is made up of three laboratories: the Synthetic Fuels Research Laboratory, the Hydrocarbon Processing Research Laboratory and the Combustion and Carbonization Research Laboratory.

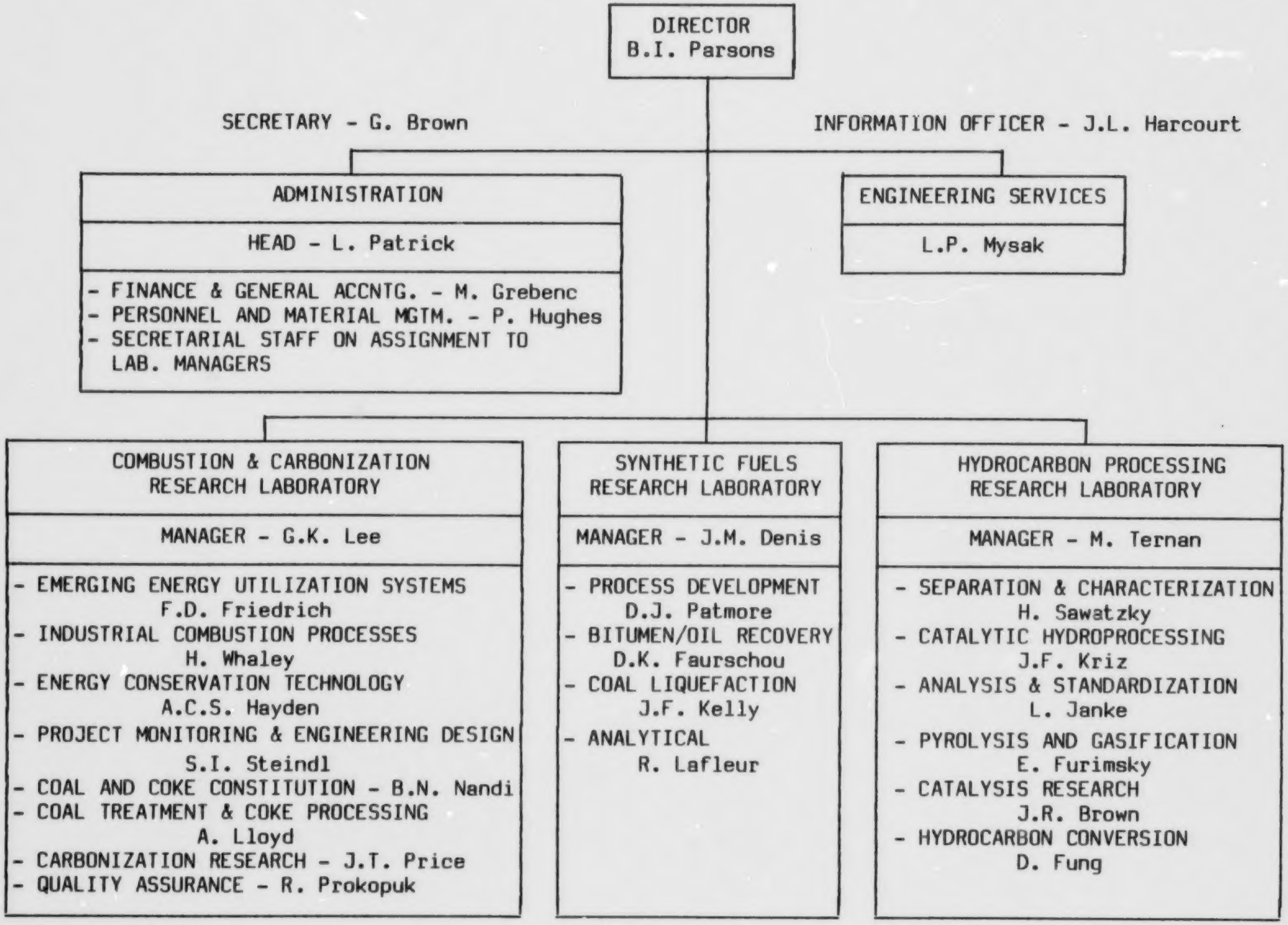
The attached organization chart indicates the major functions and the principal scientists and engineers in charge of operations. The resources assigned to the laboratories in 1984/85 were as follows:

Laboratory	Person Years	Operating $K	Salaries $K	Capital $K	Contracts $K
Synthetic Fuels Research Laboratory	51	960	2010	1525	3475
Hydrocarbon Processing Research Laboratory	37	480	1459	1655	2628
Combustion & Carbonization Research Laboratory	57	825	2247	1165	2534
Administration	22	725	867	75	
TOTALS	167	2990	6583	4420	8637

Important achievements and highlights of the year's work are summarized at the beginning of each laboratory report.

B.I. Parsons
Director
Energy Research Laboratories

ENERGY RESEARCH LABORATORIES



DIRECTOR
B.I. Parsons

SECRETARY - G. Brown

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ADMINISTRATION

HEAD - L. Patrick

- FINANCE & GENERAL ACCNTG. - M. Grebenc
- PERSONNEL AND MATERIAL MGTM. - P. Hughes
- SECRETARIAL STAFF ON ASSIGNMENT TO LAB. MANAGERS

ENGINEERING SERVICES

L.P. Mysak

COMBUSTION & CARBONIZATION RESEARCH LABORATORY

MANAGER - G.K. Lee

- EMERGING ENERGY UTILIZATION SYSTEMS
  F.D. Friedrich
- INDUSTRIAL COMBUSTION PROCESSES
  H. Whaley
- ENERGY CONSERVATION TECHNOLOGY
  A.C.S. Hayden
- PROJECT MONITORING & ENGINEERING DESIGN
  S.I. Steindl
- COAL AND COKE CONSTITUTION - B.N. Nandi
- COAL TREATMENT & COKE PROCESSING
  A. Lloyd
- CARBONIZATION RESEARCH - J.T. Price
- QUALITY ASSURANCE - R. Prokopuk

SYNTHETIC FUELS RESEARCH LABORATORY

MANAGER - J.M. Denis

- PROCESS DEVELOPMENT
  D.J. Patmore
- BITUMEN/OIL RECOVERY
  D.K. Faurschou
- COAL LIQUEFACTION
  J.F. Kelly
- ANALYTICAL
  R. Lafleur

HYDROCARBON PROCESSING RESEARCH LABORATORY

MANAGER - M. Ternan

- SEPARATION & CHARACTERIZATION
  H. Sawatzky
- CATALYTIC HYDROPROCESSING
  J.F. Kriz
- ANALYSIS & STANDARDIZATION
  L. Janke
- PYROLYSIS AND GASIFICATION
  E. Furimsky
- CATALYSIS RESEARCH
  J.R. Brown
- HYDROCARBON CONVERSION
  D. Fung

AVANT-PROPOS

Un objectif principal du programme de CANMET sur la recherche énergétique est le développement de technologies pour la conservation et l'accroissement de l'approvisionnement du Canada en combustibles fossiles liquides et ainsi réduire l'écart entre l'offre et la demande en tenant compte et du marché national et des possibilites d'exportation. Les Laboratoires de recherche sur l'énergie (LRE) se chargent des responsabilités en R&D sous cet objectif en matière de valorisation des sables bitumineux, des pétroles lourds et de la production de pétroles synthétiques; de combustion, gaséification et liquéfaction du charbon; et d'amélioration des chaudières de chauffage domestique alimentées au gaz ou au mazout. Des comités consultatifs formés de représentants de l'industrie et de clients des laboratoires aident à orienter le choix et le déroulement des projets. Des projets à frais partagés avec l'industrie sont en cours dans les laboratoires, et des parties importantes se déroulent dans le secteur industriel sous des programmes de contrats à frais partagés pour la R&D.

Le présent rapport est un résumé des activités des Laboratoires de recherche sur l'énergie pour l'année financière 1984/1985. Il s'adresse à la direction et au personnel de CANMET et il s'agit d'un document de travail devant permettre la préparation de la Revue de CANMET et d'autres publications de la Direction.

La Division comprend trois laboratoires; le Laboratoire de recherche sur les combustibles synthétiques, le Laboratoire de recherche sur le traitement des hydrocarbures et le Laboratoire de recherche sur la combustion et la carbonisation.

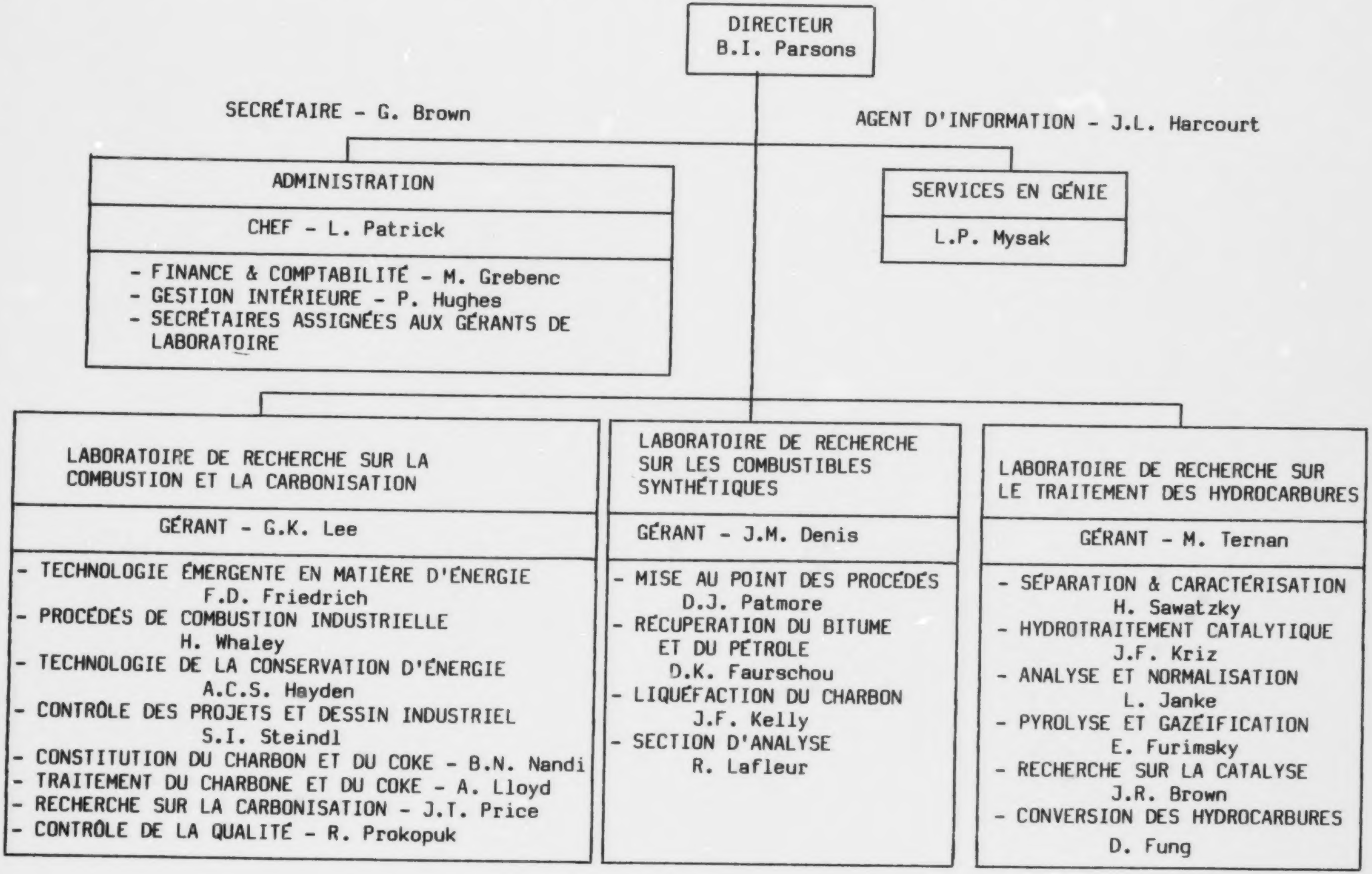
L'organigramme ci-joint indique les activités principales et les scientifiques et ingénieurs responsables de ces activités. Les ressources dont disposaient les laboratoires en 1984/1985 ont été utilisées de la manière suivante:

Laboratoire	Année-Personne	Exploitation $K	Salaires $K	Immobilisation $K	Contrats $K
Laboratoire de recherche sur les combustibles synthétiques	51	960	2010	1525	3475
Laboratoire de recherche sur le traitement des hydrocarbures	37	480	1459	1655	2628
Laboratoire de recherche sur la combustion et la carbonisation	57	825	2247	1165	2534
Administration	22	725	867	75	
TOTAUX	167	2990	6583	4420	8637

Les réalisations importantes et les faits saillants des travaux de l'année son résumés au début de chaque rapport des laboratoires.

B.I. Parsons
Directeur
Laboratoires de recherche sur l'énergie

LABORATOIRES DE RECHERCHE SUR L'ÉNERGIE



DIRECTEUR
B.I. Parsons

SECRÉTAIRE - G. Brown

AGENT D'INFORMATION - J.L. Harcourt

ADMINISTRATION

CHEF - L. Patrick

- FINANCE & COMPTABILITÉ - M. Grebenc
- GESTION INTÉRIEURE - P. Hughes
- SECRÉTAIRES ASSIGNÉES AUX GÉRANTS DE LABORATOIRE

SERVICES EN GÉNIE

L.P. Mysak

LABORATOIRE DE RECHERCHE SUR LA COMBUSTION ET LA CARBONISATION

GÉRANT - G.K. Lee

- TECHNOLOGIE ÉMERGENTE EN MATIÈRE D'ÉNERGIE
  F.D. Friedrich
- PROCÉDÉS DE COMBUSTION INDUSTRIELLE
  H. Whaley
- TECHNOLOGIE DE LA CONSERVATION D'ÉNERGIE
  A.C.S. Hayden
- CONTRÔLE DES PROJETS ET DESSIN INDUSTRIEL
  S.I. Steindl
- CONSTITUTION DU CHARBON ET DU COKE - B.N. Nandi
- TRAITEMENT DU CHARBONE ET DU COKE - A. Lloyd
- RECHERCHE SUR LA CARBONISATION - J.T. Price
- CONTRÔLE DE LA QUALITÉ - R. Prokopuk

LABORATOIRE DE RECHERCHE SUR LES COMBUSTIBLES SYNTHÉTIQUES

GÉRANT - J.M. Denis

- MISE AU POINT DES PROCÉDÉS
  D.J. Patmore
- RÉCUPERATION DU BITUME ET DU PÉTROLE
  D.K. Faurschou
- LIQUÉFACTION DU CHARBON
  J.F. Kelly
- SECTION D'ANALYSE
  R. Lafleur

LABORATOIRE DE RECHERCHE SUR LE TRAITEMENT DES HYDROCARBURES

GÉRANT - M. Ternan

- SÉPARATION & CARACTÉRISATION
  H. Sawatzky
- HYDROTRAITEMENT CATALYTIQUE
  J.F. Kriz
- ANALYSE ET NORMALISATION
  L. Janke
- PYROLYSE ET GAZÉIFICATION
  E. Furimsky
- RECHERCHE SUR LA CATALYSE
  J.R. Brown
- CONVERSION DES HYDROCARBURES
  D. Fung

CONTENTS

Page

FOREWORD i

AVANT-PROPOS iii

PART I - HYDROCARBON PROCESSING RESEARCH LABORATORY

HIGHLIGHTS 1

HYDROCARBON CONVERSION SECTION 2

CATALYTIC HYDROPROCESSING 3

- CATALYTIC INHIBITION OF SYSTEM COKING PROPENSITY 3
- COPROCESSING 3
- DEVELOPMENT OF CATALYSTS WITH OPTIMAL POROSITY 3
- HETEROATOM REMOVAL FROM HYDROLIQUEFACTION DISTILLATES 4
- DEVELOPMENT OF CATALYSTS FOR THE CONVERSION OF AROMATIC AND NAPHTHENIC COMPOUNDS IN MIDDLE DISTILLATES 5

CATALYSIS RESEARCH SECTION 5

- CHARACTERIZATION OF HYDROCRACKING CATALYST SURFACES DURING REACTION OF MODEL COMPOUNDS 5
- CATALYTIC PYROLYSIS OF PITCH AND DEVELOPMENT OF CATALYSTS 7
- ASSESSMENT OF FEEDSTOCKS FOR FLUID CATALYTIC CRACKING 7
- INDIRECT CONVERSION OF NATURAL GAS TO LIQUID FUELS 8
- DIRECT NATURAL GAS CONVERSION 9

SEPARATION AND CHARACTERIZATION SECTION 10

- SYNTHETIC CRUDE AND DISTILLATE CHARACTERIZATION 10
- SEPARATION OF PROBLEMATIC COMPONENTS IN SYNTHETIC FUELS 12
- PHYSICAL TREATMENT OF EFFLUENT STREAMS FROM IN SITU BITUMEN AND HEAVY OIL RECOVERY OPERATIONS 13

PYROLYSIS AND GASIFICATION 14

- CONVERSION OF OIL SAND COKE, OIL SHALE AND BIOMASS 14
- HOT GAS CLEAN UP AND GASIFICATION REACTIVITIES 15

ANALYSIS AND STANDARDIZATION SECTION 16

PART II - COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

HIGHLIGHTS 19

ENERGY CONSERVATION TECHNOLOGY 20

- SPACE HEATING - OIL AND GAS 20
- ENERSOLVE (INDUSTRIAL ENERGY CONSERVATION) 21
- RESIDENTIAL WOOD COMBUSTION 23
- INDUSTRIAL BIOMASS COMBUSTION 23

COAL AND COKE CONSTITUTION 24

EMERGING ENERGY UTILIZATION SYSTEMS 24

- IN-HOUSE R&D ON FLUIDIZED BED COMBUSTION 25
- CONTRACT R&D ON FLUIDIZED BED COMBUSTION 28
- DEMONSTRATION OF FLUIDIZED BED COMBUSTION 32
- TECHNOLOGY TRANSFER IN FLUIDIZED BED COMBUSTION 34

INDUSTRIAL COMBUSTION PROCESSES 35

- CONVENTIONAL COMBUSTION 35
- NON-INTRUSIVE COMBUSTION PROBES 37
- CONTROLLED MIXING HISTORY REACTOR 38
- COAL-LIQUID MIXTURE COMBUSTION 39
- ABATEMENT OF ACID RAIN EMISSIONS 41
- Technology Transfer 42

CONTENTS (cont'd)

Page

CARBONIZATION RESEARCH 42

PART III - SYNTHETIC FUELS RESEARCH LABORATORY
HIGHLIGHTS 45
BITUMEN AND OIL RECOVERY 46
    EXTRACTION OF BITUMEN FROM MINED OIL SANDS 46
    IN SITU RECOVERY OF BITUMEN AND HEAVY OIL 46
DEVELOPMENT OF UPGRADING TECHNOLOGIES FOR BITUMEN, HEAVY OIL AND RESIDUALS 47
    PILOT PLANT WORK IN SUPPORT OF CANMET HYDROCRACKING COMMERCIALIZATION 47
    FUNDAMENTAL STUDIES AND PROCESS DEVELOPMENT FOR UPGRADING OF BITUMEN AND HEAVY OIL 48
COAL LIQUEFACTION 50
    COPROCESSING RESEARCH AND DEVELOPMENT 50
    EXPERIMENTAL PROGRAM 50
    CONSTRUCTION OF COAL/HEAVY OIL COPROCESSING PILOT PLANT 51
    ADVANCED COAL LIQUEFACTION AND PYROLYSIS PROCESSES FOR CANADIAN COALS 52
ANALYTICAL SECTION 56
    SUMMARY 56
    IN-HOUSE RESEARCH PROJECTS 56
    OUTSIDE ACTIVITIES 57
    ANALYTICAL SERVICES 58

ENGINEERING DESIGN AND SUPPORT SERVICES 59
    SUMMARY 59

APPENDIX A - PROFESSIONAL, TECHNICAL AND SUPPORT STAFF 61
APPENDIX B - REPORTS, PUBLICATIONS, PRESENTATIONS AND PATENTS 71
APPENDIX C - REPRESENTATION ON TECHNICAL COMMITTEES 93
APPENDIX D - CONTRACTS, RESEARCH AGREEMENTS AND COST RECOVERY WORK .. 101
APPENDIX E - CONTACTS, MEETINGS, FIELD TRIPS, AND JOINT CONSULTATIONS 117

PART I

HYDROCARBON PROCESSING RESEARCH LABORATORY

HIGHLIGHTS

In 1984/85 HPRL continued to focus research activities on the conversion and upgrading of conventional and non-conventional gaseous, liquid and solid hydrocarbon fuels and their associated products and residues.

In-house projects carried out by forty full-time employees including fifteen engineering scientific and support staff, three physical scientists, two chemists and twenty research scientists were complemented by an active contracting-out program consisting of sixty-one ongoing contracts.

The 1984/85 budget allocated to support these internal and external technical programs was:

	$M
Salaries and benefits	1.3
Capital	1.7
Operating	0.5
Contracts	2.6
TOTAL	5.1

and resulted in the following outputs:

3	Patent applications filed
16	Refereed publications
9	Published conference preprints
22	Technical presentations at conferences
14	Technical presentations at universities and research institutes

Research highlights for 1984/85 included the formation of the Hydrocarbon Conversion Section in response to the need to coordinate efficiently the various programs of contracts and grants which are awarded to universities, para-public institutions and industry. These programs are designed to promote cooperative research and unique concepts pertinent to the development of novel energy utilization and conversion technologies. Also the first edition of the HPRL status report was published as Division Report ERP/ERL 85-12(TR). This report, which is non-confidential and thus available for general distribution, describes the various highlights of the HPRL technical program for 1984/85. A progress report for all projects within HPRL is given in the sections which follow, and include the following significant items.

In catalytic research advances were realized in the screening, testing and preparation of catalysts for coprocessing of coal with bitumen and the reduction of asphaltene content in heavy oils to meet viscosity requirements for the Interprovincial Pipeline. Studies in distillate upgrading resulted in a hydrotreating technique for the removal of heteroatoms from coal distillates and the development of metal catalysts which convert refractory aromatics in synthetic middle distillates at mild operating conditions. A new micro activity test unit was purchased to perform automated experiments in fluid catalytic cracking. Facilities for sophisticated instrumentation capable of chemically characterizing catalyst surfaces were constructed and analytical equipment was installed.

Projects related to hydrocarbon conversion resulted in the development of a promising hydroretorting technique for oil shales, and the identification of naturally occurring catalysts and adsorbents for gasification processes, all of which could significantly improve the economics of technologies employing these conversion routes. A laboratory area was constructed for a computerized experimental system for the conversion of natural gas to liquid fuels.

In separation and characterization, patent applications were filed for the use of hydrocracked pitches in road asphalt, a process for removing stabilizing components from bitumen/water emulsions and a technique for reverse osmosis fractionation of petroleum and synthetic crude fractions. Significant contributions were made to the identification of specific compound types present in various hydrocarbon fractions from conventional and non-conventional feedstocks and progress was made on the use of adsorbents and membranes for the separation of problematic components from synthetic crude distillates.

The HPRL safety committee continued its internal inspection program with a view to identifying and rectifying safety concerns in the workplace. Two building safety officers were appointed to monitor safety related items in the areas occupied by HPRL staff.

HYDROCARBON CONVERSION SECTION

The contracting-out program was designed to encourage interested organizations to apply their resources and expertise to the development of technology for utilization of Canada's natural energy resources. Considerable contributions of R&D ideas have been made through requests for proposals from the private industry sector. In some cases, novel concepts are being developed in response to unsolicited proposals from Supply and Services Canada.

There are two types of research contracts:

(a) 100% funded - the government provides total funding of R&D projects on novel and innovative ideas. Both unsolicited proposals and requests for proposals are in this category.

(b) 50/50 cost shared - the government shares a maximum of 50% of the total cost of the project with the contractor.

Projects under this program must meet the objectives defined by the CANMET Energy Conversion Program.

In addition, research grants are given to Canadian educational institutions and private sector research laboratories for projects which meet the criteria of the EMR Research Agreement Program. HPRL also assists in the recommendation of awarding the Project Research Applicable in Industry Grants funded by the Natural Sciences and Engineering Research Council of Canada.

During 1984/85, HPRL funded 61 research contracts (50/50 and 100%) under six technologies at a total cost of $2.2 million, an increase of 29% over the previous year's budget. Fifty per cent of these contracts was awarded to private companies and the other 50% to Canadian universities and para-public institutions. These contract projects (Appendix D) covered a wide range of research areas of great relevance to Canada's needs. A total of 24 reports, 13 journal publications and 5 patent applications were produced from these contracts.

CATALYTIC HYDROPROCESSING

CATALYTIC INHIBITION OF SYSTEM COKING PROPENSITY

The CANMET hydrocracking process is scheduled for demonstration in a5000 b/d plant in 1985. Support for this commercialization plan was provided by the processing of heavy feedstocks on a bench-scale reactor system, development of catalytic additives, and hydrotreatment of distillates derived from the CANMET process. In the past year, several batches of CANMET additive were prepared for pilot-scale reactor testing. Various additives were prepared and evaluated on a bench-scale system. A number of distillate fractions in the LGO and naphtha boiling ranges were hydrotreated using commercial catalysts. Additional experimental work on catalyst evaluations provided a better understanding of aspects of coking propensity.

COPROCESSING

A series of catalysts for the coprocessing of coal and heavy oil of petroleum origin was prepared and tested in a semi-batch reactor system. Experiments were performed at low pressure and at three temperatures. Based on data generated from product characterization, the catalysts were ranked in terms of coal conversion, oil production, and removal of heteroatoms from the liquid products.

DEVELOPMENT OF CATALYSTS WITH OPTIMAL POROSITY

Work continued on the development and testing of catalysts for converting asphaltenes present in heavy feedstocks to smaller molecular fragments. Special large pore alumina supports with a range of pore size distributions were prepared. Catalysts containing cobalt and molybdenum were evaluated on a bench scale fixed bed reactor unit. These studies indicated an optimal pore structure (2.0 to 0.1 µm) for the asphaltene conversion reaction network. Catalysts possessing this optimal pore structure and different metal contents are being evaluated.

CONTRACTS

1. "Upgrading of residual heavy oil by vacuum pyrolysis"

Vacuum pyrolysis was assessed as a method of upgrading oil sludges which are usually waste products from oil refinery processes. These sludges have high solid and moisture contents.

2. "Development and evaluation of catalysts for the hydrogenation of condensed polynuclear aromatics"

Catalytic hydrogenation of model compounds was studied using a novel flash hydropyrolysis technique. Several catalysts were evaluated for the production of saturated compounds.

HETEROATOM REMOVAL FROM HYDROLIQUEFACTION DISTILLATES

Operating conditions necessary for the removal of sulphur and nitrogen from coal-derived naphtha and middle distillate fractions were identified. Typical hydrotreating catalysts were tested on an automated bench-scale reactor system. Standard tests for catalyst reactivity studies using model compounds were implemented to assist in catalyst development.

CONTRACTS

1. "The impact of nitrogen compounds on the processing of synthetic gas oil"

The effects of specific nitrogen-containing compounds on the processing of synthetic gas oil was evaluated. Changes in product composition and catalyst performance were assessed.

2. "Preparation of new metal catalysts supported on ZSM5 for the deoxygenation of organic compounds"

New zeolite-supported metal catalysts were prepared, characterized and tested for deoxygenation of oxygen-containing model compounds which are present in coal-derived liquids.

3. "Software development for automated research and development reactor system in distillate upgrading"

Present process control software was upgraded and improved to facilitate more efficient and flexible operation of existing equipment for the hydroprocessing of synthetic crude distillates.

4. "Pilot scale conversion of Estevan lignite into hydrocarbon distillate by hydroprocessing using Sandwell Centrax process"

A representative distillate was produced from Estevan lignite for in-house characterization and secondary upgrading studies.

5. "Role of catalysts in heteroatom removal during hydroprocessing of model compounds"

An infrared-kinetic measurement study of the hydroprocessing of model compounds was undertaken. This resulted in a better understanding of the chemical reactions involved and relevant information necessary for the development of hydrotreating catalysts.

DEVELOPMENT OF CATALYSTS FOR THE CONVERSION OF AROMATIC AND NAPHTHENIC COMPOUNDS IN MIDDLE DISTILLATES

Highly active suported metal catalysts were introduced as a means of upgrading synthetic crude distillates. The conversion of aromatic hydrocarbons to naphthenes and the cracking of multi-ring saturated compounds were achieved at mild operating conditions. The effects of catalyst deactivation by poisoning were observed and directions for improved catalyst support development were established.

CONTRACTS

1. "Analysis of synthetic crude middle distillate fractions by 13 NMR"

Carbon-13 NMR analysis was used to monitor the conversion of aromatic hydrocarbons in in-house catalytic hydroprocessing experiments.

2. "Compositional analysis of hydrotreated middle distillate from synthetic crudes by mass spectrometry"

A low resolution mass spectroscopic method was used to identify the products from the hydrotreatment of synthetic crude distillates. The reactivities of different hydrocarbon species at the catalyst surface were then determined.

3. "Development of improved synthetic crude processes and their impact on distillate and other product qualities"

Potential product improvements in the refining of Athabasca synthetic crude using existing technology were evaluated. An understanding of the relevant hydrogenation and hydrocracking chemical processes were obtained by thorough characterization of feed and products

CATALYSIS RESEARCH SECTION

CHARACTERIZATION OF HYDROCRACKING CATALYST SURFACES DURING REACTION OF MODEL COMPOUNDS

The objective of this project was to develop improved multi-functional catalysts which optimize the hydrogenation of aromatics and remove heteroatoms (S, N, O, Fe, V, Ni, etc.) present in synthetic distillate feeds. A sophisticated surface spectroscopic technique, X-ray photoelection spectroscopy (XPS), was used extensively to directly chemically characterize the catalysts surface prior to and following exposure to heteroatom organic species representative of those found in syncrudes. This information allows determination of the activity, selectivity and poisoning rates of the catalyst and indicates possible beneficial physical and chemical modifications.

The XPS technique is unique as it can directly determine element specifiation, oxidation states and chemical composition in the upper-most 50 nm region of a catalyst. However, XPS lateral resolution is poor (several millimetres) and microprobe-type (micrometres) analysis is not possible. Preparation and chemical characterization of several catalysts for this project were completed and their exposure to heteroatom aromatics will be reported soon.

The acquisition of a scanning Auger microprobe will greatly expand the capability for investigating catalyst surface chemical and physical changes during exposure to aromatics and will complement XPS findings. This state-of-the-art multi-technique analytical microscope, a Physical Electronics Auger Multiprobe, model PHI-600 includes scanning electron (SEM) and scanning Auger (SAM) microscopy and energy dispersive X-ray microprobe analysis (EDX). It allows the imaging, complete chemical mapping and element siting of a sample surface (uppermost 50 nm) with a lateral resolution of 350 nm. Bulk chemical composition data with a lateral resolution of approximately 1 µm of this same imaged region can be done simultaneously by EDX. The analytical capabilities are augmented by a depth profiling system to monitor directly surface-bulk interface phenonoma. The PHI-600 facility was installed in the fall in a room re-modelled and specially designed for high resolution Auger microscopy training. Debugging and optimization of the many analytical functions were partially completed. The X-ray photoelectron spectrometer accessories and catalyst testing and preparation systems will be relocated to rooms adjacent to the PHI-600 in mid-1985 after extensive laboratory construction has been completed. Transfer of specimens between the two vacuum chambers while under vacuum or inert gas will be possible later this year. The combined XPS/SAM surface science facility for catalyst characterization will further Canadian catalyst R&D greatly as direct quantitative chemical measurements of the active surface/near surface region can be probed. This information will be utilized to fabricate supported metal catalysts with physical and chemical properties optimized for hydrogenation of aromatics, removal of heteroatoms and resistance to coking and poisoning.

A catalyst preparation unit employing the ion beam sputter deposition method to load metals onto porous/solid supports in clusters or thin layers was also acquired.

CONTRACTS

1. "The fabrication of thin film well defined cobalt, molybdenum-alumina catalysts and their surface chemical characterization prior to and following reactions with model compounds"

The objective of this contract, completed in November 1984, was to prepare a series of Co, Mo-alumina thin films and provide a complete surface chemical analysis using X-ray photoelectron (XPS), Auger election (AES) and secondary ion mass (SIMS) spectroscopies. It was initiated to optimize the preparatory procedures required to generate chemically reproducible CO, Mo-alumina films which due to their flat, smooth nature are better suited for quantitative surface chemical examination. After fabrication, selected catalysts were exposed to hydrogen and hydrogen sulphide to determine whether they reacted similarly to hydrotreating catalysts employed industrially.

2. "Hydroprocessing of aromatics using thin film Co, Mo-alumina catalyst surfaces"

This contract concentrated on the in situ surface characterization of hydroprocessed thin film Co, Mo-alumina catalysts fabricated by procedures developed in an earlier contract. A catalyst transfer device and a catalyst testing system attached directly to a UHV chamber and equipped with small spot size XPS (200 μm) and optimized to examine thin film catalysts is being constructed. The testing unit will permit catalyst evaluation up to 10 atm pressure and 600°C and in situ examination. Resulting information may lead to the fabrication of improved HDS/HDN/HDO/HDM catalysts and also benefit surface catalyst testing studies initiated in-house.

CATALYTIC PYROLYSIS OF PITCH AND DEVELOPMENT OF CATALYSTS

Great difficulty was experienced in feeding molten pitch into the fluidized bed reactor. Furthermore, the bed material (catalyst) agglomerated with sticky pitch during fluidization. For these reasons, testwork was restricted to pyrolyzing pitch premixed with catalyst in a fixed bed reactor. The results indicated that with a commercial -alumina catalyst about 25% low sulphur, metal-free and rather volatile liquid fuel could be recovered from pitch while gaseous fuel was estimated to be 10%.

CONTRACT

1. "Literature review on pitch utilization and technical proposal for a catalytic pitch conversion system"

This contract deals with a comprehensive literature review on industrial applications of pitch and the development of a database on physical and chemical properties of pitch from different sources so that researchers will have access to reliable data on pitch feedstocks. Technical proposals were also invited for the design and construction of a catalytic pitch conversion system, with emphasis on solving technical problems encountered in-house.

ASSESSMENT OF FEEDSTOCKS FOR FLUID CATALYTIC CRACKING

The objective of this project is to experimentally evaluate and predict the performances of various non-conventional synthetic crude gas oils for FCC operations in Canadian refineries. Therefore, a fully automated microactivity test unit with both fixed bed and fluid bed reactors was installed and is being debugged and commissioned.

CONTRACTS

1. "Hydrogenation and its effects on fluid catalytic cracking unit feedstocks"

The objective of this contract is to assess the benefits of hydrogenation followed by catalytic cracking of gas oils (both conventional and synthetic crude gas oils) versus direct cracking and to determine the extent to which hydrogenation can enhance liquid fuel yields with less coke formation.

2. "Evaluation of metal-tolerant fluid catalytic cracking catalysts by molecular probes"

The objective of this contract is to develop an understanding of the catalytic cracking processes involving the use of modern metal-tolerant catalysts. Both product yield and molecular yield data obtained from micro-activity testing of pure components and their blends commonly found in heavy oils and synthetic crudes will allow an assessment of the performance and properties of the metal-tolerant catalysts used in cracking processes. This will provide a tool and background data for evaluating other catalysts which will be developed for upgrading FCC feedstocks.

3. "Study of incorporating heavy oil and synthetic crude residua into FCC feedstock"

The objective of this contract was to evaluate the viability of producing transportation fuels from heavy oil and synthetic crude residue by incorporating these materials into fluid catalytic cracking feedstocks. Microactivity test yield data along with the available computer models were used to predict the performance of various feedstocks in commercial FCC units. The work will lead to greater utilization of indigenous synthetic crudes in Canadian refineries.

INDIRECT CONVERSION OF NATURAL GAS TO LIQUID FUELS

The objectives of this project are to develop Fischer Tropsch catalysts with increased product selectivity for producing high quality diesel fuel from natural gas so as to decrease Canada's dependence on imported crude and to establish a blending stock for the hydrogen deficient distillate liquids. The construction phase of a fully automated high pressure flow reaction system is continuing. A multizone computerized furnace was interfaced with a computer, pneumatic lines were installed and preliminary testing was made. Construction and automation of the receiver systems werecompleted. A novel concept which allows considerable shortening of the synthetic hydrocarbon mixture analysis time was worked out and all components acquired. Also, the plant area was remodelled in order to assure a clean environment for the computerized controls.

CONTRACTS

1. "Carbon deposit morphology on metal surfaces during hydrocarbon synthesis"

The objective of this contract was to address the question of the possible effectiveness of the various forms of the surface carbon in the Fischer-Tropsch synthesis of hydrocarbons. Nickel and iron surfaces were compared to obtain more information about the performance of these two metals in relation to the Fischer-Tropsch process.

2. "The automation of a high pressure reactor system"

This contract dealt with engineering, construction and automation of a receiver system for a high pressure automated reaction system and suitable automated software development.

3. "Direct production of aromatic hydrocarbons/gasoline from synthesis gas"

This contract dealt with the development of Fischer-Tropsch catalysts which were used in combination with zeolite catalysts (HZSM-5 developed by Mobil and "X" developed by a Canadian research lab.) to produce gasoline from synthesis gas in one step. The Fischer Tropsch catalysts were MnO or zirconia base impregnated with active metals Ni and Co at various concentrations. The reactions were studied in a fixed bed reactor (both mixed catalyst bed or following catalyst bed) at 250-300°C and atmospheric pressure. Results are encouraging since about 55% of the hydrocarbons produced was aromatics-rich gasoline with high octane number. Chemical composition of liquid product was determined by GC/MS.

4. "Direct production of gasoline range hydrocarbons from syngas in a dual bed reactor system"

This contract is an extension of the one above. The two best Fischer Tropsch catalysts combined with the two zeolite catalysts (HZSM-5 and "X") will be tested in dual fixed bed reactors each having independent temperature control. Reactions will be studied from 250°C to 400°C and at 0.1-2.0 MPa. The construction of a 13-mm dual bed reactor system was completed and testwork will start soon.

DIRECT NATURAL GAS CONVERSION

Direct conversion processes for liquid fuel synthesis have been reviewed. One direct route being pursued is the dehydrogenation/polymerization route. The development of this technology requires research in two main areas: dehydrogenation of methane by high temperature pyrolysis and the polymerization of acetylene/ethylene intermediates to liquid fuels. Development work in the first stage of this process is being funded under EMR's 50/50 contracting-out program. There is considerable scope in controlling the selectivity of the low temperature catalytic reactions of acetylene. A number of amorphous and crystalline catalysts were prepared for the conversion of acetylene to liquid fuels. These catalysts will be tested in a bench-scale continuous flow tubular reactor.

1. "Conceptual design and techno-economic assessment of three reactor systems for hydrocarbon production from natural gas"

The objective of this contract was to evaluate the technical and economic feasibility of producing liquid fuels by pyrolyzing natural gas to acetylene/ethylene and processing the acetylene to the desired fuel. Three reactor types and appropriate ancillary equipment are being evaluated, i.e., a resistance-heated reactor, a pre-heated hydrogen reactor and a plasma arc reactor.

2. "Technical and economic assessment of producing distillate fuels via an electricity based process"

The objective of this contract was to carry out preliminary experimental runs on the production of acetylene by pyrolysis of methane in a hydrogen-methane plasma arc. These experiments established optimal operating variables (feed flowrate, pressure and temperature) in order to obtain the highest arc efficiencies.

3. "Methane conversion to hydrocarbons in a hollow cathode arc"

The objective of this contract was to explore the potential of the hollow cathode arc for carrying methane conversions. This work demonstrated that saturated aliphatic hydrocarbons can be obtained directly from methane in quantitative yields in a single high temperature process.

4. "Preparation and characterization of pentasil zeolites"

This contract dealt with the synthesis of crystalline aluminosilicates of the pentasil family which will be used to convert acetylene/hydrogen to liquid fuels. The work also involved the preparation and characterization of a series of catalysts.

5. "Direct partial oxidation of methane to methanol over designed heteropoly catalysts"

This contract focused on the direct conversion of natural gas, whose major component is methane, to methanol using a heterogeneous catalyst. Methanol appears to be the most convenient liquid obtainable from methane and has the advantage of being versatile as a feedstock for a variety of petro-chemical processes, including it's conversion to gasoline.

SEPARATION AND CHARACTERIZATION SECTION

SYNTHETIC CRUDE AND DISTILLATE CHARACTERIZATION

A major part of this project concerns the utilization of unwanted synthetic and processing residues. The utilization of these residues would contribute significantly to the economic viability of synthetic crude production operations such as the CANMET hydrocracking of bitumen/heavy oil/residua. A systematic approach is being taken by characterizing the various types of components in both the pitches and the candidate base stock. The characterization results are then used to predict their compatibilities. Also the characterization data can be used to tailor asphalt blends to desired specifications. During 1984/85, the methods for obtaining relevant characterization information have become more sophisticated. Processing residues other than from CANMET hydrocracking, such as visbreaking and Eureka pitch, were also studied.

Some of this work was carried out at the TOTAL Oil Company in France as a cooperative effort by a visiting CANMET scientist. Another part of this project relates to studies on the effect of recovery methods on the processability of in situ recovered bitumen/heavy oils. This was proposed as a Canada/US tar sand cooperative project and was approved in principle by the Executive Committee of the US/Canada Memorandum of Understanding. Meetings were held with technical representatives of the U.S. Department of Energy, the Alberta Research Council, the Saskatchewan Heavy Oil Laboratory and CANMET to develop appropriate work statements and to allocate tasks. Work statements were developed for the US to study the recovered bitumen from an American operation involving steam stimulation. The corresponding work statement for Canada involved heavy oil from a fireflooding recovery operation. Formalapproval from the Executive Committee is awaited for implementation of the work plan.

Other characterization efforts concern the products from the coprocessing of bitumen residua with coals. A detailed investigation is being made of synthetic crudes from coprocessing reactions under different reducing gases such as hydrogen and synthesis gases. This also involves the study of polycyclic aromatic compounds as well as hydrocracked bitumens.

Other areas include the study of synthetic crude middle distillatesat various hydroheating severities, determination of molecular weight distributions of heavy fuel and their synthetic crude products, as well as assessing synthetic crude naphtha qualities for refining feedstocks.

CONTRACTS

1. "Diesel and middle distillate quality and yield improvements"

This work concerned the maximizing the amount of light cycle oil and heavy gasoline obtained from the catalytic cracking of gas oil with large synthetic crude content with the goal of blending into the diesel fuel pool. A major portion of this work involved hydrotreating and hydrogenation to obtain the maximum cetane value. This was followed by direct diesel engine characterization and studies are in progress for establishing the amounts that can be blended into various diesel fuels.

2. "Analytical methods development and characterization requirements for the Canada/U.S. cooperative projects on resource characterization"

This contract is concerned with the Canada/U.S. cooperative tar sand projects. The first project identified a number of factors believed to contribute to error in analytical procedures. These will be investigated and new procedures will be developed to minimize these effects. The other portion of the contract concerns the analytical requirements that have been assigned to CANMET as part of its contribution to the project.

3. "Selective identification of olefins and paraffins in middle distillates of synthetic crude oils"

Thermal processing of bitumen/heavy oil/residuals often produces olefins which are responsible for gum formation and oxidation leading to storage problems. Characterization of olefins, n-paraffins and other saturated compounds in middle distillates identify conditions that promoteor inhibit formation of undesirable components in the production and storage of diesel fuels of proper quality. Gas chromatography-mass spectrometry was used in conjunction with infrared and nuclear magnetic resonance spectroscopy to characterize these compounds.

4. "The compositional study of nitrogen and oxygen compounds in products of heavy oil primary and secondary upgrading processes"

This contract concerns the study of nitrogen and oxygen compounds present in various synthetic crudes and a raw bitumen in order to better characterize components having deleterious effects on storage stability. Three distillate cuts - naphthas, middle distillates, and gas oils - have to be separated into classes. Polar compounds and extracts were further separa-ted into subfractions which are analyzed by mass spectrometry, infrared and ultraviolet spectroscopy. This characterization improves the understanding of the fate of nitrogen and oxygen in upgrading processes.

5. "Determination of molecular weight of asphalt samples by gel permeation chromatography"

This work involved the determination of the average molecular weight of asphalt samples, pitches and their constituents (maltenes and asphaltenes).This information is complementary to compound-type distributions available for these samples. The average molecular weight results could explain some of the rheological properties of asphalt cements such as viscosities, softening point, etc. It is already well known that asphalt blends prepared in our laboratory from processing residues have lower average molecular weight than conventional asphalts.

SEPARATION OF PROBLEMATIC COMPONENTS IN SYNTHETIC FUELS

The separation and removal of various synthetic crude components can lead to significant benefits during upgrading to transportation fuels. Removal of nitrogenous and sulphurous components would obviate the need for hydrodesulphurization of middle distillates at temperatures which are thermodynamically more favourable. Separation of saturated components from aromatic materials would allow processing of only the lower quality materials thus reducing costs. Technologies are being studied for these separations are reverse osmosis, sorption and extraction.

Components having the greatest affinity for the membrane materials are preferentially permeated through the membranes in reverse osmosis. Through affinity chromatography, several membrane materials were identified as possessing the desired affinities for specific components and are being investigated in membrane experiments. Separation of aromatics from saturated hydrocarbons by reverse osmosis has been developed with separation factors that have commercial feasibilities. There is much scope for improvements and this is being studied, along with other desired separations such as the removal of nitrogenous and sulphurous components and the separation of higher boiling distillates.

Studies on the selective sorption of nitrogenous and sulphurous components concentrated on the former until now because the nitrogenous compounds are the most problematic and dictate the severity of processing. During 1984/85, both zeolites and ion exchange resins were investigated for their abilities to remove nitrogenous components from synthetic crude naphtha fractions. It was found that certain zeolites and cation exchange resins could separate the nitrogenous components at capacities that are within industrial feasibility. Work is continuing to improve these separations as well as develop new sorbents with commercial possibilities.

CONTRACTS

1. "Impact of problematic components on synthetic crude processing"

The objective of this work was to extract nitrogenous components and accompanying metals from heavy synthetic crude fractions, bitumen/heavy oils and residua and to determine the effects on fluid catalytic cracking. On several gas oils including Syncrude, Suncor and IPPL, it was possible to selectively extract nitrogenous components with polar solvents which increased significantly catalytically cracked gasoline yields. Heavier material resulted in poor separations, non-selective extractions or poor extractions and generally were disappointing.

2. "The separation of saturates and aromatics from syncrude middle distillates"

The objective of this contract was to evaluate several solvents for their ability to extract low fuel quality components from synthetic middle distillate fractions with the goal of isolating a small volume stream available for severe refining without the loss of higher fuel quality components. Previous work identified sulphur dioxide as an effective solvent, but the necessary operating conditions made it undesirable for large-scale refining. The most promising solvent as determined by small-scale batch experiments will be used in a bench-scale continuous extraction unit with Syncrude middle distillate to obtain sufficient volumes of product for diesel engine testing and for other product specification testing. The optimal operating case will be the basis for an economic assessment of the process in comparison with the direct upgrading of the original feed, as currently practised.

PHYSICAL TREATMENT OF EFFLUENT STREAMS FROM IN SITU BITUMEN AND HEAVY OIL RECOVERY OPERATIONS

The objective of this work was to produce better quality water from the aqueous effluents from in situ bitumen and heavy oil recovery operations by physical means. Both membrane and sorption technologies were investigated. In the sorption case, industrial solid wastes were used for the removal of oil. Water of desired qualities can be obtained by ultrafiltration but where the water is too hard more costly reverse osmosis is needed.

CONTRACT

1. "Evaluation of adsorbents for treating stable oil/water/mineral emulsions produced during in situ bitumen/heavy oil recovery operations"

Emulsions of oil and water are formed during in situ recovery of bitumen and heavy oil in Western Canada. The objective of this work was to develop a physical method by using inexpensive sorbent materials for treating effluent streams from bitumen and heavy oil in situ recovery operations for the production of acceptable water for steam raising or for release to the environment with maximum recoveries. It was demonstrated in-house that some waste materials can break emulsions successfully. Part of this work is to recover the bitumen/heavy oil from the filter cake by physical treatment or by solvent extraction methods similar to those used by Suncor. This method is an alternative to chemical methods which require the addition of expensive surfactants and polymers.

2. "Technical and economic assessment of the application of membrane technology for treating oil/water/mineral emulsions"

The objective of this contract was to expand on the preliminary in-house work on the use of porous membranes for treating produced water emulsions from in situ bitumen and heavy oil recovery operations and upgrading these emulsions to boiler feed quality water for reuse in the recovery operation. This work identified several membrane materials that permeate water of boiler feed quality from a field sample as well as being temperature and fouling resistant. Future work will include the use of these selected membranes at higher temperatures, with regular fouling/cleaning cycles, evaluation of their performance in smallest scale commercial units (still considered to be bench scale), and with produced waters from varied sources with different oil loadings, salt and hardness content. An economic assessment of optimal performance with the commercial units will be the basis for a field testing program on oil producers' sites.

PYROLYSIS AND GASIFICATION

CONVERSION OF OIL SAND COKE, OIL SHALE AND BIOMASS

The substitution of heavy oils for conventional crudes in existing refinery operations has resulted in a substantial increase in coke residue. Furthermore, developing technologies such as coal pyrolysis and coprocessing produce unconverted char and pitch. Gasification of these unwanted materials would improve the economics of the above processes by yielding synthesis gas which can be employed to supply hydrogen for existing hydrotreating operations or be used as a feedstock for the production of high quality diesel fuel for blending with the lower quality product from the primary refinery processes. In 1984/85 studies concentrated on the reactivity of Suncor and Syncrude cokes in steam and steam/air mixtures using various gasification techniques.

Canada possesses reserves of oil shale which have the capacity to yield large quantities of hydrocarbons ideally suited to the production of diesel fuel. However, information on the yield potential of the shales and technical data on the properties of the associated liquids are scarce. Studies carried out in 1984/85 indicate that Eastern Canadian oil shales have liquid yields comparable to USA shales being considered for commercial development and that these yields can be potentially doubled by employing a new hydroretorting technique.

Biomass may play an important role as an energy source in remote population centres to which the transportation of coal or liquid fuels is uneconomic. An awareness program was maintained in 1984/85 with a view to investigating the possibility of low cost electricity generation based on wood gasification.

CONTRACTS

1. "Integrated oil shale retorting system"

To obtain technical data on the two stage process for retorting of New Brunswick oil shales (first stage) and subsequent co-combustion of spent shale with Minto coal (second stage).

2. "Rapid pyrolysis of New Brunswick oil shales"

To determine the yield of liquid products during rapid pyrolysis of oil shales.

3. "Optimization of hydrogen retorting of eastern shales"

To identify the optimal experimental conditions for hydrogen retorting of Eastern shales.

4. "Evaluation of processing options for the oil shale of Ontario"

To assess potential routes for commercial utilization of oil shale reserves in the province of Ontario.

5. "Assessment of Nova Scotia oil shale reserves"

To assess the potential of oil shale reserves in Nova Scotia for industrial utilization.

HOT GAS CLEAN UP AND GASIFICATION REACTIVITIES

The utilization of the products from the gasification of coal in combined cycle power generation represents one of the most efficient coal conversion routes. However, the product gases must be purified as they contain undesirable sulphur compounds. This usually involves cooling of the product gases which adversely affects the viability of the gasification process. If the purification of the products can be carried out at gasification temperatures the economics of this alternative would markedly improve. In 1984/85 various naturally occurring minerals as well as some low cost material were evaluated as potential adsorbents for sulphur containing compounds at high temperatures and were compared with existing adsorbents.

The costs of existing gasification processes are adversely affected by the severity of operation. Studies on the gasification characteristics of Canadian coals demonstrated that certain low rank coals contain mineral matter which increases carbon conversion. These feedstocks containing mineral components with a high "catalytic activity" for gasification would improve the economy of the gasification route by decreasing the required processing severity.

CONTRACTS

1. "Gasification of oil sands coke"

To determine gasification reactivities of Suncor coke and Syncrude coke in a fluidized bed reactor.

2. "Production of gasoline from coal washery rejects by indirect liquefaction"

Economic evaluation of production of gasoline from coal rejects at Sparwood's preparation plant via gasification to synthetic gas, methanol synthesis and Mobil MTG process.

ANALYSIS AND STANDARDIZATION SECTION

In 1984/85 this group of three professionals and six technicians provided analytical support to research and industrial clients by carrying out 30 000 determinations on 3000 solid and liquid fuels and related materials. These analytical services were complemented by continued contributions to national and international standards organizations and by coordination of the CANMET Service Program for the Evaluation of Coal Standards (CANSPECS) round robin coal sample exchange program.

Analytical support activities concentrated on the determination of the physical and chemical properties of feedstocks, products and residues from research projects related to the production, utilization and conversion of hydrocarbon fuels as well as coals submitted through the Canadian Commercial Coal Survey Program. The complex relationships which exist between these physical and chemical parameters were identified and verified with a view to assessing the progress of novel technologies or evaluating the market potential of Canadian coals.

Within Canada, public and private sector organizations employ both American Society for Testing of Materials (ASTM) and International Standards Organizations (ISO) procedures in order to evaluate coal quality.

These standards are continually reviewed and new procedures developed to respond to the need to assess wider ranges of coal quality or to evaluate properties which have an impact on novel technological applications.

To ensure that new and revised procedures implemented by ASTM and ISO are compatible with Canadian interests the Analysis and Standardization Section at ERL continued to contribute to the deliberations of these standards groups in an advisory and consultative role.

As a complement to participating in the activities of these organizations the section continued to coordinate the CANSPECS. This program distributes commercially produced Canadian coals to 50 laboratories within Canada and abroad for analysis of specified parameters of coal quality. The experimental data obtained are employed for the assessment of the analytical acceptability of proposed standards and the evaluation of laboratory performance with respect to existing standards.

PART II

COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

HIGHLIGHTS

A significant component of the combustion and carbonization research effort during the past year was devoted to the extrapolation and transfer of completed research to industrial applications. This evolution of in-house research into practice was accompanied by new initiatives of a fundamental nature related to projects having mid- to long-term objectives.

Technology transfer activities, many of which involved projects funded by the EMR Coal Division, included:

a) Canada's first commercial bubbling fluidized-bed at CFB Summerside in Prince Edward Island;

b) a low NO_x/SO_x retrofit burner demonstration for pulverized coal at CFB Gagetown;

c) an evaluation of the combustion and emission performance of a novel wood-refuse fired boiler at Campbell River, B.C;

d) fuel efficiency and heat absorption assessments of nine energy-intensive industrial processes;

e) industrial field trials to establish the feasibility of replacing heavy oil with a coal/water slurry in an iron ore induration kiln at Labrador City;

f) correlations between coal quality and wall pressures in full-scale coke batteries.

Scientific input was also provided to a number of external organizations including other government departments, industry, universities and research laboratories on a wide range of topics ranging from innovative burner designs to the coking potential of coals from new seams.

The conventional flame and fluidized-bed combustion projects addressed several critical barriers to the clean, efficient burning of coal, with significant progress being made in non-intrusive, laser probing of flames, the characterization of sulphur sorbents for fluidized-bed systems, and the design of a circulating fluidized-bed pilot plant.

In carbonization research, two projects succeeded in utilizing lower-quality coking coals while maintaining coke quality. One approach was to formulate new blends which take advantage of the longer batch time available for coking as a result of reduced steel production. The other approach uses inexpensive pitches and bitumen-like additives to enhance coke quality, and thus offset the effects of lower-grade coals. In a separate project, bench-scale studies of the anisotrophy of coke have led to improved methods of interpreting results from CCRL's technical-scale coke ovens.

In energy conservation a major objective to develop a gas furnace which would improve the efficiency of home heating by 20 to 30% was achieved when the retrofit condensing flue furnace developed by CCRL was placed on the market in the USA. Marketing in Canada awaits the approval of regulatory authorities. Another objective was achieved with the adoption by the Canadian Gas Association of a standard for the measurement of seasonal efficiency of gas furnaces, which is based largely on CCRL work.

During the year the staff published 28 papers, prepared 60 divisional reports and participated in over 30 media interviews, seminars and presentations. Staff strength remained unchanged at 56 person years.

ENERGY CONSERVATION TECHNOLOGY

SPACE HEATING - OIL AND GAS

The objective of this program is to reduce consumption of fuels for space and service water heating through improved combustion technology and operational conditions, while ensuring safety and minimal environmental degradation.

Major emphasis is directed to the evolution of technology and strategies to replace oil with natural gas as the primary space and water heating fuel. By developing retrofit devices and new designs of combustion systems to improve burner/furnace efficiency, to reduce potential unsafe operating conditions with present systems and to encourage more energy efficient housing, efficiency improvements of 20 to 40% are possible on gas. By using substitute and degraded liquid fuels, additional oil may be available for the transportation sector.

In-house laboratory R&D on new technologies for space and water heating is continuing with additional projects in the field, mainly by contract. Development of specific advanced technologies is also carried out by contract to industry. Seasonal performance experimental procedures are being developed and new designs produced, with the results transmitted to standard writing agencies, testing laboratories, manufacturers and government agencies through standards committees, published papers, seminars, associations, e.g., Canadian Standards Association, Canadian Gas Association, Canadian Wood Energy Institute, Ontario Petroleum Association and Canadian Home Builders Association and through close cooperation with individual manufacturers and utilities. Liaison is also maintained with U.S. developments, particularly relating to environmental concerns and alternative technologies.

The retrofit condensing furnace, developed with CCRL participation, which can augment the efficiency of the existing gas furnace in the home by 20-30%, has now been placed on the market in the U.S.A., although regulatory authorities have not yet approved the unit in Canada. Additional technical support is presently being given to a Canadian manufacturer by CCRL, to help illustrate to these authorities that the unit is not only more efficient, but also considerably safer than the existing gas furnace on its own. The field trial of this equipment has been extended to the end of this heating season, with both power burner and no-draft hood configurations added. In a related area, a paper was presented on the excellent suitability of methanol for condensing furnace applications, due to the high dew point and latent heat produced from methanol combustion.

The third phase study on plastic heat exchangers with industrial support is complete, having examined alternative plastics and material assembly/bonding techniques. A polyethylene/polypropylene co-polymer, similar to that used in the first prototype, is the most suitable material for the range of temperatures and corrosive media to be encountered. Two new prototypes are now being constructed using the new material with actual manufacturing-type bonding techniques and an optimized fan/motor control system.

The standard for seasonal efficiency measurement of gas furnaces has now been adopted by the Canadian Gas Association (CGA). Experimental and analytical development of a similar standard for gas boilers is now under way. A paper was presented to the Canadian Standards Association on the needs and techniques required for a similar standard for oil-fired equipment.

A detailed paper on the problems of design, installation, deterioration and upgrading of chimneys in Canada was presented as the background paper for the Canadian Standards Association, in cooperation with the Canadian Electrical, Gas and Oil Associations, to define technical needs in this area. Another paper was presented to the Air Pollution Control Association on means to ensure safe, efficient operation of heating systems in tight housing. Technical support is also being given to CMHC on field performance and modelling of venting of combustion appliances and to CSA on new standards for chimneys.

In cooperation with the oil industry, a series of experiments is under way to examine the effect of fuel quality degradation. Phase I results indicated that increasing aromatics and/or viscosity can lead to burner problems. Phase II studies are examining the potential for in-line nozzle heaters and high pressure burners to extend the range of operation.

A high efficiency, low-air-requirement oil furnace for northern applications is being developed, under contract. Potential fuel savings are 30%, relative to a conventional furnace, without the problems of condensing. Preliminary design work is under way, with a working prototype to be produced in 1985/86.

ENERSOLVE (INDUSTRIAL ENERGY CONSERVATION)

The ENERSOLVE program is concerned with increasing the efficiency of utilization and reduction of consumption of oil and gas in industrial processes. Much of the present industrial equipment, particularly if more than 10 years old, may not be operating or even operable at maximum attainable efficiency of fuel use. Scope exists to technically upgrade most installations to attain greater fuel economy. The program is intended to support a limited number of specific studies on retrofit of combustion systems in a variety of industrial sectors and regions of Canada. By this means, a fully documented capability for energy conservation will be formulated by the performers, enabling them to subsequently and privately offer such services to industry in general, perhaps even with a guaranteed pay-back.

Twelve pre-engineering studies, including on-site testing, were carried out in the following industries:

(1) lime kiln
(2) waste wood fired boiler
(3) direct-fired process drier
(4) sewage gas-fired boiler
(5) municipal district heating system
(6) vegetable oil processing
(7) acid plant heater
(8) cement kiln
(9) brick kiln
(10) chemical processing boiler
(11) uranium processing boiler
(12) solid waste-gaseous-fuelled food processing boiler

An updated report on the results of all twelve trials is being prepared, highlighting the performance results obtained and the recommendations for efficiency improvements, including the cost effectiveness of various options. The report will also present general methodology for testing and analytical procedures for the determination of the efficiency of industrial combustion systems.

During the ENERSOLVE studies it was found that Canadian industry often uses rigid procedures developed for steam-raising boilers with specific fuels to determine performance without realizing the simplifications or complexities required for other industrial processes or for different fuels. It has become apparent that there is a significant lack of knowledge of the fundamentals of combustion system analysis and of the major potential benefits that may accrue from improvements to that system. It is important that the general principles, industrial results and the fact that there are now Canadian consultants who are developing the skills to provide such a service to industry should be made widely known.

A detailed technology transfer program is now being set up by the Industrial Energy Division (IED) of ECOS. CCRL is working closely with this group to ensure that the findings of ENERSOLVE reach effectively the widest possible audience through a detailed combustion manual and audio-visual training package. To ensure technical reliability and compatibility with ENERSOLVE results, CCRL is writing the technical manual/module on comubstion, one of a number of manuals being prepared for IED.

Presentations have been made on these studies to the Energy Steering Committees of the Industrial Energy Conservation Task Forces and of the Association of Consulting Engineers, outlining the major opportunity for consultants in this area of industrial combustion, providing their techniques and procedures are correct. Additional detailed technical seminars to the consulting engineering sector are to be given later this year.

Direct contact was made with a number of the Industrial Conservation Task Forces, including Mining and Metallurgy and with the Ferrous Energy Research Association. CCRL will work with these organizations to develop specific technical combustion guidelines related to their needs.

Two potential industrial sites for a retrofit flue gas condensing system on a gas-fired unit were identified. Contracts have been let to carry out detailed analyses for these two potential applications of this technology offering major efficiency gains, which have now been realized in the residential sector.

RESIDENTIAL WOOD COMBUSTION

Wood stoves have been shown to be an efficient and often cheap way to heat a house. However, often significant amounts of incomplete combustion products can be produced, resulting in a potential fire safety hazard if deposited in the chimney in the form of creosote, or in a severe air pollution problem, in areas of poor fumigation. Efforts have been directed towards changing the design of these appliances to improve combustion performance and generating techniques by which the performance can be effectively measured.

In 1984/85, the primary thrust of the domestic wood heating program was to provide technical support to North American standards for the determination of efficiency and emissions of free-standing wood stoves. CCRL has been extremely active on the committees of the Canadian Standards Association (CSA) and the American Society for Testing and Materials (ASTM). These two organizations are working to develop such a test standard for Canada and the U.S.A., respectively. A number of major components of these standards are the result of research carried out at CCRL, including the test fuel configuration, a model predicting the change in wood ultimate analysis over the burn cycle and the methodology for data reduction.

In addition to carrying out further work to finalize these standards, an experimental program is being carried out to extend the standard to cover central heating appliances. Other efforts are primarily geared to develop techniques or strategies to improve the performance of existing appliances in the field, particularly for areas such as Whitehorse, where a severe air pollution problem can be traced directly to the use of wood burning appliances.

INDUSTRIAL BIOMASS COMBUSTION

Scientific and technology support was provided to the NRC Bioenergy Program and the Energy from Forest Program (ENFOR) on matters relating mostly to technology transfer and development. Under ENFOR, two contracts were initiated on the comubstion of wood refuse for steam raising in the pulp and paper industry and a number of energy from wood proposals for research funding were adjudicated. The NRC Bioenergy Program was assisted in the monitoring of a contract for combustion of peat in small industrial boilers and in the development of a seminar on research needs for small biomass-fired boilers.

COAL AND COKE CONSTITUTION

Past work has shown how to apply the water-gas shift reaction (CO + H_2O) to the upgrading of naturally oxidized thermal and coking coals from Western Canada. During 1984/85 the same technique was applied successfully to the transformation of low-rank (subbituminous and lignite) coals into coking coals. A major breakthrough was made by demonstrating that inexpensive blast furnace gases containing about 25% CO can be used to bring about the same degree of improvement as expensive pure CO under suitable conditions.

Studies on the characterization of naturally oxidized Canadian coals using ^{13}C nmr and Fourier Transform Infrared techniques were carried out. Using these methods, in relation to more conventional approaches, it is possible to estimate the extent of oxidation of Canadian coals. This will be of great utility where stockpiling of coals is concerned and also for characterization of coal fines from coal washery plants.

Combustion tests on a wide range of coals (Canadian and foreign) were made using the in-house drop tube combustion furnace. Fluidized bed combustion tests were also carried out on the same set of coals in collaboration with Dr. J. Vleeskens of the Netherlands Energy Foundation. It was thus possible to compare the behaviour of these coals in both pulverized fuel and fluidized bed combustion situations. The unexpected and important finding from this work is that coal characteristics which lead to good combustion in a pulverized fuel boiler do not necessarily lead to good fluidized bed combustion, and vice-versa. These phenomena are being studied in more detail.

The formation of solid residues in the processing of bitumen from tar sands is an undesirable side reaction. The origin of these residues is a problem of great importance to bitumen processing. In collaboration with Prof. K.J. Laidler of Ottawa University, a study of the kinetics of coke formation from chromatographically separated fractions of bitumen was completed. A wide variation in both reaction rate and type of coke formed has been observed. This work has direct application to the CANMET hydrocracking process.

EMERGING ENERGY UTILIZATION SYSTEMS

This section devotes most of its efforts to expediting the application of fluidized bed combustion (FBC) technology to the Canadian energy picture. In most western nations, FBC is viewed primarily as a technology for the environmentally-benign utilization of high-sulphur coal. In Canada, additional applications are perceived, including combined firing of coal and wood waste in the pulp and paper industry; utilization of waste materials such as coal washery rejects; and combustion of residues from heavy oil upgraders. Unfortunately, none of these markets is large enough to generate a strong, private-sector development of technology specifically suited to Canadian needs, therefore federal support is required to ensure that FBC proceeds to maturity as rapidly as possible.

Major objectives of the CCRL program are:

- to demonstrate the environmental benefits of FBC boilers in an industrial setting;
- to develop a bank of combustion performance data, for a range of Canadian coals and other solid fuels, to aid designers of FBC equipment;
- to develop a data bank on the performance of various Canadian limestones as sulphur sorbents;
- to support other agencies in the development of FBC technology by appropriate means.

IN-HOUSE R&D ON FLUIDIZED BED COMBUSTION

Pilot-Scale Program

CCRL Mark II bubbling bed FBC

The CCRL Mark II fluidized bed combustor is a versatile pilot-scale research facility which was installed at the Bells Corners laboratories in 1980. Important features are a combustor cross-section of 380 mm x 400 mm, variable in-bed heat transfer surface, provision for either over-bed or in-bed feed, separate weigh feeders for fuel and sulphur sorbent, and provision for re-injection of fly ash from a multicyclone dust collector. Since its commissioning, the Mark II facility has been operated with a variety of coals and other fuels, to develop a bank of combustion performance data which will ultimately be required by designers of full-scale systems. Much of the pilot-scale work has been in direct support of the CFB Summerside demonstration, which is described later.

Four test programs were conducted during FY 1984/85; a relatively short series of 7 combustion tests with Syncrude coke and Fort McMurray limestone, to complete an investigation begun the previous year; a series of 23 combustion tests with Brogan coal from Cape Breton, and Havelock limestone from New Brunswick, to obtain comparative data for the CFB Summerside demonstration; a series of 13 combustion tests with rice husks, using a sand bed, as part of a program on biomass combustion being carried out by a visiting fellow from Yugoslavia, and 4 tests with paper-and-sandust pellets, conducted at the request of a consultant in Prince Edward Island.

Significant improvements were made to the feedstock supply systems. Larger bunkers, each with a weigh feeder were provided for fuel and limestone. These permit accurate control of thermal input and Ca/S ratio. Various parts of the gas and solids sampling systems were also improved.

CCRL Circulating FBC

A second generation fluidized bed combustion concept, known as circulating FBC, has been demonstrated to have advantages over bubbling-bed FBC in terms of ability to cope with unreactive fuels and reduced limestone requirement for sulphur capture. Since the majority of large FBC applications in Canada would probably benefit from the application of circulating FBC, a decision was made in 1982 to equip CCRL with a pilot-scale combustor of this type.

By contract, a detailed design was prepared by July 1984 of a complete facility, including a 0.3 in. diam. combustor, fuel and limestone feed systems, a cooling water system with variable heat extraction from the combustor, flue gas cleanup, and all instrumentation and controls. Most of the major auxiliary components, such as blowers, baghouse, conveyors, cooling tower, etc., are now on order. However, due to a series of contractual problems, an order has not yet been placed for the most important component the combustor and primary cyclone assembly. Fabrication of this assembly is predicted to take nine months from date of order, hence completion of the circulating FBC facility will be delayed until FY 1986/87.

Bench-Scale Program

Coal reactivity parameters

The wide range of coals available in Canada which may ultimately find application in FBC systems, makes it highly desirable to have a means for quickly, economically obtaining some measure of their relative performance in an FBC combustor. CCRL accordingly undertook to develop a bench-scale FBC and an empirical procedure for ranking coals and other fuels in terms of reactivity.

A suitable apparatus was completed in 1982. Subsequently a procedure was developed in which a sample of fuel is batch-fed to the preheated combustor, and the rate of CO_2 evolution is used as a measure of reactivity. A sophisticated flue gas analysis system coupled with computerized data processing provide a rapid, inexpensive test procedure.

During the past year, further improvements were made to the equipment, notably the installation of a new feeder which permits automatic operation with coals ranging from minus 30 mesh to 25 mm dia. Numerous tests, using fuel charges of different weight and size consist, over a range of temperatures, were conducted with five well-known industrial coals. This work has been undertaken to provide what may be described as a calibration of the procedure. Results are being analyzed in terms of a parameter called the mean carbon residence time.

A report describing the apparatus and procedure was published in June 1984. Another report, presenting results for the five coals studied, is in preparation.

A large number of tests have also been carried out on a variety of biomass fuels, in support of a program being carried out by a visiting fellow from Yugoslavia.

SO_2 sorbent reactivity

Early work on sulphur capture in fluidized bed combustion showed that limestones and dolomites vary greatly in their ability to react with SO_2; e.g., to achieve a given level of sulphur capture, stone from one deposit might require a Ca/S ratio of 2, while stone from another deposit might require a Ca/S ratio of 5. Differences are related primarily to the porosity and hardness of the stone, as they affect the surface area available for reaction with SO_2.

There being virtually no information available on the sulphation capacity of Canadian limestones CANMET's Mineral Sciences Laboratories undertook to investigate a range of stones which are candidates for application to fluidized bed combustion. A study of the literature revealed that the usual method of evaluation, based on thermogravimetric analysis has shortcomings because it does not simulate the dynamic conditions of a fluidized bed. MSL therefore undertook the development of a fluidized bed bench scale apparatus (50 mm diam.) and procedure which would provide resultscorrelating more closely with full-scale experience.

Development of the apparatus and test procedure was completed in 1983. Since then, about 30 Canadian limestone samples have been evaluated, and the results have been cross-checked against thermogravimetric analysis and pilot-scale results obtained from several combustors. Through the cooperation of the IEA Committee on AFBC, 10 stones from Norway and Sweden were also tested, and results were found to compare well with full-scale experience. The data were then used to develop a computer model, based on a model developed at the Argonne National Laboratory, which predicts sorbent performance in full-scale combustors. Thus, the initial objective of the work has been fully met.

Further work in 1984 investigated the feasibility of enhancing the sulphation capacity of low reactivity limestones by various means. The most successful of these proved to consist of grinding the limestone to less than 0.15 mm, then pelletizing to the 2 to 6 mm size required for satisfacotry operation of the fluidized bed. The pelletized material has larger pores hence more surface area than the native stone and thus achieves a sulphation capacity of about 50%, compared with 15 to 40% for the native stones. This effectively reduces the issue of limestone reactivity to a matter of the cost of grinding and pelletizing the less reactive deposits. In addition, the bench-scale apparatus was used to evaluate several Alberta limestones for the AOSTRA/CANMET/Industry Upgrading Residue Utilization Project.

This project is now largely completed, and has been reported, including a paper given at the International Conference of FBC in London, October 1984. There is still some ongoing work on the effects of coal ash constituents on the sulphation capacity of limestone. Depending on the source of the coal, ash constituents may enhance or retard sulphation capacity.

Bench-scale circulating FBC

Circulating FBC is perceived as the most promising technology for the utilization of residues such as coke and pitch from the upgrading of tar sands and heavy oil. However, these materials contain relatively high concentrations of alkalis and vanadium, which may cause boiler tube corrosion.

Beginning in FY 1984/85, the Mineral Sciences Laboratories undertook to investigate the disposition of vanadium, sulphur and alkali, the corrosion caused by them, methods to capture or stabilize them, and if possible, the recovery of vanadium and nickel from the ash. A 50-kw circulating FBC, 100 mm in diam., has been built. Unfortunately construction took much longer than anticipated, and the delay was compounded by start-up difficulties, with the result that the apparatus was not fully operational until the end of the fiscal year.

Analysis of carbon in FBC residues

When firing coal, it is necessary to determine the carbon content of the solid residues for calculating boiler efficiency. In the case of a fluidized bed boiler utilizing limestone for sulpher capture, the ash streams contain up to 40% CaO, which is a strongly reactive/desiccant even at temperatures of 450°C. This constitutes a potential source of error in the procedure for carbon determination since, even if the samples taken from the bed drain or baghouse are immediately placed in sealed containers, they are exposed to air during grinding prior to analysis. The conventional ASTM procedure for carbon determination, which measures weight loss after ashing in a muffle oven, records (reactive - bound) moisture loss as carbon loss, and thus gives a carbon content which is too high. This can be avoided by performing an acid extraction to remove carbonates (unreacted limestone) along with reacted CaO ($CaO + H_2O - Ca(OH)_2$) prior to the ashing step. This does not however, overcome the fact that the sample, once it has taken up moisture, is no longer representative of what came out of the boiler.

The assistance of the Mineral Sciences Laboratories was enlisted, and several samples were analyzed using a thermogravimetric/differential thermal analysis technique. This led to an understanding of the mechanisms taking place, and may be worth pursuing to the point of developing a new analytical technique. To obtain better data on the rate at which samples may pick up moisture, CCRL has ordered a controlled humidity cabinet. Further work will be undertaken in cooperation with MSL, probably on samples from the 10 000-h FBC corrosion test at Point Tupper, N.S.

CONTRACT R&D ON FLUIDIZED BED COMBUSTION

Queen's University - Fluidized Bed Combustion R&D

FY 1984/85 was the second year of a two-year contract under which Queen's University conducted extensive and varied research on FBC.

Using a pilot-scale combustor essentially identical to the CCRL Mark II combustor, the following trials were carried out to establish performance data and help clarify fundamental combustion and sulphur capture mechanisms:

- 8 trials with Devco coal, Calpo limestone and Irish Cove limestone
- 9 trials with Syncrude coke and Athabasca limestone
- 1 trial with Syncrude coke and Havelock limestone
- 16 trials with Evans coal and Havelock limestone
- 2 trials with Minto coal and Havelock limestone

The final report on these trials is in preparation.

In addition, to support the mathematical modelling activities of the IEA Committee on AFBC, some bench-scale experiments were carried out, and a general model of FBC combustion, developed separately as a doctoral thesis, was further refined prior to distribution to members of the IEA Committee.

A work statement was prepared and a new two-year contract was negotiated.

Queen's University - ASPEN Simulation

ASPEN is a comprehensive computer model for simulating industrial processes. It's main value is in design optimization. Through the Unsolicited Proposal Program, Queen's University was contracted to simulate the Summerside FBC boiler plant, using the ASPEN program, and thus provide a powerful, reliable tool for costing and optimizing new FBC installations.

Work is proceeding on schedule, and is about 40% complete. Most of the effort in 1985/86 will involve simulation of results and validation, and the contract should be completed early in 1986/87.

Polymath Corp. Circulating FBC Tests with Syncrude Coke

A contract sponsored by CANMET in 1981 demonstrated that Syncrude coke could be burnt efficiently, with excellent sulphur capture, using circulating FBC technology. Since the utilization of such fuels is of continuing interest to governments and industry, it was deemed desirable to follow up the initial work with a more comprehensive pilot-scale study, which would employ Fort McMurray limestone as the sulphur sorbent, and would provide a more complete materials balance, including information on the fate of heavy metals.

A detailed work statement was prepared in 1983/84, and the requisite feedstocks were procured. However, for budget reasons, calling of tenders for the pilot-scale combustion trials was deferred to 1984/85. Because of various difficulties a contract was not awarded until March

1985. The work will be carried out during 1985/86, using the pilot-scale facilities of A. Ahlstrom Ltd. in Finland.

Babcock and Wilcox Canada Ltd. - FBC Tests with Coal/Water Slurries

Coal/water slurries (CWS) are perceived as a cost effective way to utilize coal in furnaces designed for oil or natural gas, but difficulties have been encountered with flame stability and atomizer wear. One possible solution to these problems is to utilize a fluidized bed as a primary combustor, and the existing oil or gas-fired boiler as a waste heat boiler. Since there has been little experience with fluidized bed combustion of CWS,and none with CWS made from Canadian coals, a contract for some pilot-scale tests was let in 1983/84 to Babcock Wilcox Canada Ltd. CANMET provided three test fuels: a beneficiated, low-ash CWS, made by the CARBOGEL process, containing about 30% water; an unbeneficiated, high-ash CWS, containing about 40% water, and a thickener underflow from a Western coal preparation plant, containing about 70% water. The work was carried out in a 1 ft x 1 ft combustor at the B&W Research Centre in Alliance, Ohio.

Results with the first two fuels were fully satisfactory in that stable, complete combustion was readily achieved, under conditions similar to those used for dry coal. However, it was not possible to obtain autogenous combustion of the thickener underflow. To maintain bed temperature it was necessary to supply about 30% of the heat input as support fuel, in the form of dry coal.

The final report was received early in 1984/85, and a paper based on this work was presented at the 8th International Conference on FBC, Houston, Texas, March 1985.

E.E. Berry - Utilization of FBC Residues - Phase II

This small contract on the use of FBC residues as a soil cement, addressed a knowledge gap identified in the broader Phase I study. Unfortunately, laboratory tests carried out under the contract demonstrated that while the residues have good cementing properties, they have freeze/thaw characteristics which render them inadequate for road-building applications.

Both the Phase I and Phase II studies were funded by the Coal Division of the Coal and Alternative Energy Branch of EMR, with CCRL providing the Scientific Authority.

It is concluded that despite their high CaO content, uses for FBC residues are limited to 1) aggregate for road asphalt, 2) neutralization of acidic wastes, and 3) liming of acid soil, provided that it can be shown that there is no problem with uptake of soluble heavy metals.

Technical University of Nova Scotia - Burning Rate of Single Coke Particles

This contract was let in the hope of gaining information that would assist in mathematical modelling of FBC. Suncor coke was chosen as the feedstock because it is easy to obtain particles in the desired size range of 10 to 25 mm, and because it was expected that, being low in volatiles, there would be little fragmentation. The proposed experimental procedure is to inject coke particles of known dimensions and weight into a preheated fluidized bed combustor, after a given time quench the combustion process, retrieve the coke particles, and re-weight them. Burning coke can then be calculated from weight loss, surface area and time at combustion temperature.

Progress has been limited because of equipment problems and an unexpectedly high degree of particle fragmentation. The contract will be completed in 1985/86.

BBC Engineering and Research Ltd. - Development of a Plug Feeder for Coal

In response to an unsolicited proposal, a contract was let for a series of bench-scale tests aimed at developing a simple, reliable feeder capable of delivering coal into pressure vessels such as coal gasifiers or pressurized fluidized bed combustors. The feeder principle has already been demonstrated and commercialized in applications involving various forms of biomass; the purposes of the present tests were to establish design criteria and probable performance characteristics when feeding coal, which is significantly less resilient than biomass.

The testwork showed that coal plugs of sufficient gas impermeability can be formed at reasonable compaction pressures. Essentially impermeable plugs can be made if the coal has a partial size of less than 10 mm, and a few per cent of surface moisture. Measurements were made of wall friction and Poisson's ratio, for a range of input conditions, and semi-empirical mathematical correlations were developed.

The present contract was completed. A logical next step would be to conduct tests with a proto type feeder, but no decision has yet been made.

Luscar Ltd. - Circulating FBC Utilization of Coal Washery Rejects

This contract followed up a previous study in which Luscar Ltd. investigated the technical and economic feasibility of providing heat for coal drying by burning coal washery rejects in a bubbling-bed FBC. In the present study, the feasibility and costs of circulating FBC technology were reviewed, and the scope was expanded to include the generation of 30 MW of electricity as well as heat for coal drying. Participants in the study were Luscar Ltd., Trans Alta Utilities Corp., Lurgi Canada Ltd., and Combustion Engineering Canada Ltd.

The work was performed in two phases. In the first, process flow diagrams were prepared, and capital costs estimated, for each of three cogeneration scenarios; generation of 10, 20 and 30 MW of electricity plus provision of hot gas for coal drying. These were then evaluated, and the 30 MW scenario was selected as the most promising. In the second phase, a detailed plant layout, major equipment specifications, and estimates of capital costs, operating costs, and availability were prepared for the 30 MW option.

It is concluded that such a plant, capable of generating 30 MW of electricity and drying 600 t/h of coal, would cost about $45 million. Overall availability is estimated at 75%. In the opinion of Luscar and Trans Alta, the project is not economically viable under the circumstances prevailing at Luscar's Coal Valley mine. However, the same approach may be viable at other sites.

University of British Columbia - Heat Transfer from Circulating Fluidized Beds

CANMET has signed a research agreement with the Chemical Engineering Department of UBC, with the objective of building a probe for direct measurement of heat transfer coefficients in a fluidized bed. During the first year of the agreement, UBC completed the design of a platinum - coated heated probe which is expected to have high sensitivity. To permit testing, extension of the agreement has been recommended.

DEMONSTRATION OF FLUIDIZED BED COMBUSTION

FBC Heating Plant at CFB Summerside

Since 1977, EMR has been collaborating with Defence Canada in the construction and demonstration of a fluidized bed heating plant at CFB Summerside, P.E.I. EMR's technical input to the project has been almost entirely through CCRL, which coordinated the design contracts, and since completion of the plant in December 1982, has been planning and conducting the demonstration program.

The plant consists of two boilers, rated at 18 t/h of steam each. They were designed to burn high-sulphur Eastern Canadian coal, with at least 80% sulphur capture by means of limestone addition to the bed. An additional requirement was that they be capable of co-firing wood chips to provide up to 30% of the heat input at any load.

During the first and half of the second heating seasons (82/83 and 83/84) efforts were concentrated on overcoming operating difficulties, primarily in materials handling, calibration of the automatic controls, operator training, and boiler acceptance tests, all with coal as the only fuel. By May 1984 the boilers had been tested with three different Cape Breton coals having sulphur contents ranging from 4 to 6%, and guarantees of capacity, efficiency and emissions control had been met with all of them. Also in May 1984 some brief tests showed that over 50% of boiler capacity could be achieved firing wood chips alone.

The demonstration program for the 1984/85 heating season consists of boiler performance tests with another four Eastern Canadian coals, tests to determine maximum rate of load increase, and the overlap in capacity between one-bed and two-bed operation. The planned program was interrupted in February when, with about two-thirds of the work completed, one boiler was forced out of service by a tube leak. Erosion by bed material proved to be the cause of the tube leak. While investigation showed that a recurrence of this failure is preventable, a general erosion of the in-bed surfaces is a potential problem that requires close monitoring. The program will continue after repairs are made to the boiler.

Point Tupper 10 000-h FBC Corrosion Study

In order to evaluate the corrosion/erosion performance of candidate boiler tube materials under the severe conditions typical of a utility FBC steam generator, EMR has provided most of the funding for what is to date the most comprehensive FBC corrosion test program in the world. Other participants are Nova Scotia Power Corporation, which is running the program, and Combustion Engineering Canada Ltd., which designed and built the test equipment as well as making a financial contribution.

The program involves exposing a range of ferritic and austenitic alloys to temperatures ranging from 500 to 700°C in a FBC combustor having a cross-section of 1 m^2. A total of about 800 specimens will be exposed for periods up to 10 000 h, in 1000-h increments.

CANMET's Physical Metallurgy Research Laboratories are responsible for the metallurgical evaluation of the specimens. The Energy Research Laboratories, through CCRL, are involved in the project management and in a scientific advisory capacity concerning control and measurement of combustor performance. In the latter content, considerable effort was spent in a detailed review of analytical procedures and algorithms for materials and heat balance. CCRL has also undertaken sponsorship of contract in which flue gas analyses in the freeboard and the bed will be conducted.

The 8th 1000-h campaign was completed in February 1985. The full program of specimen exposure should be complete by late summer, 1985, although metallurgical evaluation and data analysis will take two or three years to complete.

Circulating FBC Utility Boiler Demonstration at Chatham, N.B.

In August 1984, Treasury Board approved EMR Coal Division funding of a major demonstration project; the construction of a 20 MWe circulating FBC utility boiler at the Chatham generating station of New Brunswick Electric Power Commission (NBEPC). Besides being the largest FBC boiler yet built in Canada, and the first to operate at the high steam pressure and temperature conditions required of utility boilers, this unit will be unique in that it will be co-fired with high-sulphur New Brunswick coal and oil shale. The latter feedstock serves both as supplementary fuel and, because of its significant calcium content, as supplementary sulphur sorbent.

The project is being managed by NBEPC, and site preparation was under way by the end of 1984/85. The contract for design and construction of the circulating FBC boiler was awarded to Combustion Engineering Canada Ltd., in cooperation with Lurgi GmbH. Commissioning of the boiler is scheduled for late 1986.

CCRL has been represented on the Management Committee for the project since its beginning, and thus was heavily involved in preparing tender specifications and bid evaluation. More recently, an officer of CCRL was invited to chair the Technical Subcommittee responsible for detailed planning the demonstration program. Although the full membership of the Subcommittee, which is expected to include representatives from the Canadian Electrical Association and other utilities, has not yet been recruited, three meetings have already been held between NBEPC and CCRL. Substantial effort will be required in the coming fiscal year.

Although the relationship to the Chatham project is indirect, it is worth mentioning that CCRL is represented on the Management Committee of a contract being funded by the Canadian Electrical Association, which will investigate the utilization of residues from circulating FBC boilers. A request for proposal has been issued, and the work is expected to be completed in 1985.

TECHNOLOGY TRANSFER IN FLUIDIZED BED COMBUSTION

IEA Agreement on AFBC

In 1980, under the auspices of the International Energy Agency, nine nations including Canada signed the "Implementing Agreement for Cooperation in the Field of Atmospheric Fluidized Bed Combustion in Industrial or District Heating Boilers". Canada's participating projects are all CCRL projects, namely the CFB Summerside demonstration, the CCRL in-house R&D program, and the R&D program contracted to Queen's University. Therefore the Canadian representative to the Agreement has also been from CCRL.

Two meetings of the Executive Committee were held, one in May, in Christchurch, New Zealand, and one in October, in London, England. At the first meeting, the rotating chairmanship of the Executive Committee was transferred from Canada to Norway. A five-year work plan was prepared, and a useful one-day technical session was held. The main business of the second meeting was to discuss a possible joint program on mathematical modelling of FBC. Since this is not an area where CCRL has strong expertise, a contract was issued to Professor Becker of Queen's University, which enabled him to serve as an advisor. Professor Becker's research group has developed a general mathematical model of FBC. It was agreed that the IEA joint program could begin by having several of the participants run the Queen's program on their own computer. The predictions would then be compared with their own measured data. Where existing sub-routine proved inadequate, they could be improved by pooling data generated by all participants. The program will be distributed to interested participants as soon as an adequate set of operating rates have been prepared.

INDUSTRIAL COMBUSTION PROCESSES

Canadian industries and utilities are in the process of converting from premium fuels to indigenous and often low quality coals. In many cases, these coals are from newly-developed deposits and have unknown characteristics; reliable data on their combustion heat transfer and emission characteristics are non-existent. The CCRL coal combustion research program reflects the increasing importance of coal in our domestic energy requirements and also supports Canadian coal exporters in their drive to secure a reasonable share of the world market. An industry/government collaborative program has been established in which the utilities and coal suppliers participate under the CANMET Minerals and Earth Science Program.

The objectives of the conventional coal combustion research group are described below.

CONVENTIONAL COMBUSTION

The overall objective is to study the combustion performance, heat transfer and emission characteristics of Canadian coals and rejects for conventional power generation and industrial use, both in Canada and in support of the export market. Specifically to:

- produce a periodically updated reference data bank of the combustion performance and emission characteristics of commercially important Canadian coals;

- collaborate with industry in the determination of significant combustion performance characteristics of newly developed coal deposits for electrical power generation and industrial use;

- assess the effects of coal cleaning on the flame heat transfer, deposition and emission characteristics of Canadian thermal coals for utility and industrial applications;

- conduct fundamental studies of the ignition, devolatilization and combustion burnout of unreactive Canadian coals and reject materials.

Low-grade Coal for Electrical Generation

The general objectives of this project are to evaluate the combustion, slagging and fouling properties of coals from Canadian coal deposits for use in power utility boilers and to minimize emissions from conventional coal combustion furnaces by control of flame properties through burner and furnace design, chemical additives, flue gas clean up and coal feed comminution. Specific objectives of each coal combustion project undertaken are to:

1) determine the combustion and handling characteristics of the coal,

2) evaluate the combustion performance at various feed fineness and excess air levels,

3) characterize the particulate and gaseous pollutants generated during combustion,

4) assess the slagging and fouling potential of ash constituents on radiant heat transfer surfaces and superheater tubes respectively,

5) determine the fly-ash resistivity characteristics and the ease of fly-ash collection by electrostatic precipitation, and

6) develop combustion charts for each coal or coal blend studies.

The equipment used to investigate these properties is a pulverized-coal fired utility boiler, which embodies two opposed low-swirl burners and has a full-load firing rate of 2.5 GJ/h. The twin burners can be located in three basic positions on the furnace to vary the combustion chamber residence times. It is estimated that at 90 kg/h feed rate and 30% excess air, the residence time can be varied from a minimum of 1.0 to a maximum of 2.7 depending on where the burners are located.

During 1984, 31 coal combustion evaluations were performed in the pilot-scale utility boiler. Fourteen of these evaluations were undertaken as cost-shared coal combustion projects with 5 Western Canadian coals and one eastern Canadian coal. The remaining 17 coal evaluations were undertaken on an in-house basis to determine the effect of residence time and coal comminution (using various furnace configurations) on combustion characteristics of various grades of coal. This in-house project is essential to assessing the operation of the present boiler, when it is compared to the results which were obtained from the previous boiler (in operation at CCRL from 1954 to 1982). The preliminary results, relating the basic combustion performance of the six cost-shared coals investigated in the utility boiler have been reported to the three coal companies concerned, and the in-house assessment of boiler performance is in progress.

Coal as a Substitute for Oil in Industry

To facilitate the use of coal in place of oil in industrial combustion systems, data must be obtained which compare the combustion and heat transfer characteristics of coal with those of fuel oil under similar aerodynamic conditions. The CCRL tunnel furnace (1 m diameter and 4.25 m long) has a refractory-lined precombustion chamber (1.2 m long). It is designed to fire pulverized coal, light and heavy fuel, natural gas and coal-liquid mixtures. It has a thermal input of about 2 GJ/h and has a continuous access slot along its length for the insertion of flame probes.

These probes can measure a range of parameters which define spatial temperature, flow and concentration profiles within the furnace together with emission levels at the furnace exit. Heat transfer, both convective and radiative, can be measured along the flame length. It is also possible to partially refractory line the furnace to simulate a number of industrial process heater configurations ranging from boilers (unlined) to kilns (80% lined). Thus, the furnace has the flexibility to undertake burner comparative studies, coal vs fuel oil or natural gas, and industrial configuration changes.

Six thermal coals, five Western Canadian and one Cape Breton have been evaluated in the tunnel furnace. These range from high-volatile to low-volatile bituminous and in one case the coal was unreactive. The data evaluation and reporting of these combustion tests are nearing completion. The data generated in these experiments are being used for CCRL tunnel furnace model validation under contract.

NON-INTRUSIVE COMBUSTION PROBES

Conventional techniques for measuring flames require that a probe be inserted into the flame in order to measure specific parameters or to extract a sample for analysis. As a result the conventional probe must be water cooled so as not to be damaged. Conventional or intrusive probes will therefore disturb the flame in two ways. The large water-cooled probe will disturb the velocity field and while the water cooling keeps the probe at a constant temperature, it also removes heat from the flame.

The influence of the intrusive probe on the mixing and heat transfer processes in the flame will be most critical in regions of recirculating flow which are influencial. CCRL has initiated a program to develop non-intrusive laser diagnostic probes, for measuring temperature, gas composition and velocity and particle size distribution within pilot-scale flames.

The coherent anti-Stokes Raman spectrographic (CARS) technique can be used to measure temperature and species concentration. To enable the visualization of phenomena in the flames generated in the laboratory a laser Schlieren setup is used. The laser doppler anemometry (LDA) technique is envisioned for the measurement of gas velocity and particle size distribution.

An optical arrangement has been developed to perform the CARS experiments. The dye laser, which produces the stokes beam, has been constructed and is undergoing an extensive series of characterization tests. There are four major aspects of the dye laser beam which are being studied: the spatial, temporal and spectral profile of the beam and the timing of the dye laser pulse. The holographic grating, spectrometer with the fibreoptic link have been built and their operating characteristics have been studied. The next step, experimentally, is to link the source side optics (the lasers) with the detection side optics (the holographic grating spectrometer) via the fibreoptic.

In order to deduce temperatures or species concentrations, the CARS beam which is generated at the measurement point in the test section, is analyzed using the holographic grating spetrometer.

The dispersed signal is digitized by an optical multi-channel detector (OMD) and analyzed by means of specially written computer programs on a VAX computer. This software is tailored to the operating characteristics of the optical arrangement, using experimentally determined slit functions and dispersions. The final step in the development of a CARS experiment is the physical linking of the apparatus with the VAX computer. Presently there exists a logical link to the computer, whereby data are recorded on a floppy disk and hand carried to the computer. In order to accelerate the data acquisition and information transfer, investigations are under way to install a serial and ultimately a parallel link-up to the computer. Computational speed is enhanced by using specially developed fast-fitting programs.

A greater understanding of the physical processes taking place in a flame can be gained if these processes are made visible. The development of the laser Schlieren technique at CCRL will make it possible to observe small scale phenomena, such as the flame front around a burning coal particle and large scale phenomena, such as a burning turbulent eddy. The Schlieren technique has been demonstrated in bench scale flames and is ready to be investigated in pilot-scale flames in the CCRL tunnel furnace facility. The apparatus is portable and incorporates conventional as well as novel techniques for image enhancement. High speed cine pictures of burning coal particles have been taken at exposure times of 40/μs. With a few minor improvements, the technique should be ready to apply to industrial-scale flames in the near future.

CONTROLLED MIXING HISTORY REACTOR

In order to better understand the reaction history of individual burning coal particles, CCRL has designed and built a furnace, termed a controlled mixing history reactor (CMHR). This device can simulate an environment which is typical of that encountered by coal particles as they pass through a flame, but without the added complication of aerodynamic flow patterns found in coal furnaces and combustors.

Because of the variability of the burning characteristics of different coals, a rapid yet simple method of evaluating coal reactivity is needed and it is anticipated the CMHR will fill this need. The furnace consists of a vertical ceramic tube heated from the outside by glow bar heaters. Pulverized coal ($\approx$100 μm) is carried from a fluidized bed feeder where it passes down the heater tube in a flow of air. The residence time of the coal is less than 1 s and the feed rate is about 20 mg/s. The coal particles are subjected to a heating rate of the order of 10^4K.s^{-1}.

A variety of techniques can be used to sample the devolatilization and combustion products. A total sample probe can be inserted from the bottom of the furnace to collect an area averaged sample at any axial location. Also, optical probes will be used to measure radial and axial temperature and composition profiles.

The reactor has been installed and a microprocessor based temperature controller has been incorporated in the control circuitry. This was done to gradually raise the device to temperature to alleviate thermalshock problems.

The heat and mass transfer phenomena in the furnace have been modelled extensively using physical and computer models. Based on these studies a variety of recommendations have been made to improve the performance of the furnace. These models have also been used to predict the conditions inside the furnace and calculate particulate temperatures. Studies are currently under way to investigate the use of two particle diameters for the calculation of fluid mechanic and heat transfer properties.

CONTRACT R&D

1. "Performance prediction of the CCRL tunnel furnace for coal combustion"

The objective of this contract is to improve the existing computer model and to expand its capability to include low-volatile coals. The end result will be a well documented program which will be used to complement the pilot scale combustor and to improve the accuracy of the scale up computations.

The program has been installed and verified on the computer at CCRL and experiments are under way to verify the predictive capabilities of the program for conditions in the tunnel furnace while burning low-volatile coals.

COAL-LIQUID MIXTURE COMBUSTION

The use of coal to replace premium liquid fuels is a goal of Canadian energy policy but this replacement has been inhibited by the inconvenience of handling solid fuel and by its environmental implications. The department's strategy for energy aims is to remove this inhibition, by bringing new coal utilization technologies that have both economic and environmental advantages over premium fuel alternatives, to a stage of development useful to industry. A program of development and commercialization of fuels made from mixtures of coal with liquids, with the twin objectives of easy, economic coal handling and minimized environmental impact has therefore been a major EMR/CANMET objective for the past eight years.

Specifically, the objective is to develop and evaluate coal-liquid mixture (CLM) preparation and combustion technology as an alternative to the use of premium liquid and gaseous fuels in Canadian utility and industrial applications and in those situations where conventional coal combustion technology cannot be readily used. The program will:

- establish a database of the combustion and heat transfer characteristics of a number of CLM fuels through contract and in-house research, and in collaboration with foreign agencies;

  study by contract the potential derating effects of the conversion of oil-designed boilers to CLM fuels;

- provide technical support to the coal/water slurry (CWS) demonstration programs being sponsored by EMR's Coal Division at the Chatham Generating Station of the New Brunswick Electric Power Commission; and planning for the Charlottetown CWS demonstration in an oil-designed boiler;

- participate on behalf of Canada in the International Energy Agency (IEA) CLM Implementing Agreement and its annexes in the development of both in-house and contract programs to resolve the problems of reduced burner life through abrasive wear, poor atomization performance and carbon conversion efficiency as well as resolution of the relationships between slurry rheology, handling characteristics and atomization quality;
- participate with industry in other programs which would endeavour to develop CLM technology for process heating purposes.

New Brunswick Electric Power Commission, Chatham, N.B. - Generating Station Demonstration of CWF Technologies

In April 1982, EMR, the New Brunswick Electric Power Commission (NBEPC) and Cape Breton Development Corporation (CBDC) entered into a collaborative agreement to demonstrate the preparation of CWS and its utilization in utility boilers.

This agreement provided for the construction of a 4 t/h CWS pilot plant located in Sydney, N.S. It also specified that burners should be developed and tested in the 12.5 MWe unit No. 1 front-wall fired boiler and the 22 MWe tangentially fired unit located at the Chatham, N.B. generating station. The project was administered by a management committee comprised of representatives of EMR Canada, NBEPC, CBDC, the Nova Scotia Power Corporation (NSPC) and AB Carbogel, the CWS process developer. Technical input to the project was through a technical committee, which in addition to management committee members, includes representatives of the National Research Council (NRC), Ontario Hydro, New Brunswick Research and Productivity Council and the Centre for Energy Studies of the Technical University of Nova Scotia. Burners have been developed and installed on each of the two Chatham units and the test program on each unit was completed in late 1984. Reporting of the demonstration is well advanced with final reports expected in early 1985.

IN-HOUSE R&D

CCRL has undertaken an R&D program in support of the ongoing demonstration program in CLM technology. The combustion, heat transfer and emission characteristics of potentially commercial coal-liquid mixtures is being established in a program being undertaken in the CCRL tunnel furnace. The coal-water slurry being used at Chatham has been studied and compared with the parent coal feedstock as pulverized coal, and with No. 6 fuel oil. As part of the CANMET involvement in burner development, a burner has been developed which incorporates some novel atomization and wear resistance features. The burner will be studied using CWS fuel and No. 6 fuel oil using a commercial atomizer for reference purposes. The burner was also tested under contract in Chatham Unit No. 1 as noted below.

CONTRACT R&D

Contract R&D on the application of CLM technology is also designed to support the ongoing demonstration program and complement the in-house program.

During 1984/85 four contracts were in progress, with others planned, leading to burner development and potential short-term demonstrations of CLM technology in industrial applications:

1. "Determination of the combustion and heat transfer parameters of a number of coal-water mixtures" - International Flame Research Foundation (IFRF) IJmuiden, The Netherlands.

This project is in collaboration with The Netherlands and is in association with the IEA-CLM agreement Annex II, base technology. It involves the study of seven coal-water mixtures covering a range of coal types (20-37% VM) and a range of slurry manufacturers. The experimental work was completed in March 1984 with a final report in October 1984.

2. "Testing of prototype CWF burners at Chatham, N.B." - New Brunswick Electric Power Commission.

This project was a test of a single NRC/CANMET ceramic atomizer using CWF in Chatham Unit No. 1. Another burner showing some promise was also tested, but the tests were terminated due to mechanical problems. The final report on this contract is scheduled early in 1985.

3. "An assessment of potential CWS atomizers and burners for application to industrial combustion systems in Canada" - R. Grossman, Consultant.

The primary objective of this contract is to assess the state-of-the-art of CWF burner development in North America. The Chatham project has shown that the burner/CWS rheology/atomization quality/relationships are not known, and many burner manufacturers are making claims which cannot be quantified. The contract will document what the major suppliers are now producing.

4. "Determination of the combustion and heat transfer characteristics of CBDC coal-water mixture in comparison to heavy fuel oil" - Centre for Energy Studies (CES), Technical University of Nova Scotia.

This program is complementary to that undertaken at the IFRF. CES has acquired the necessary equipment to undertake flame characterization using the CWS being used at Chatham, N.B. The NRC/CANMET ceramic atomizer tested at CCRL and Chatham, will be used in the CES work.

ABATEMENT OF ACID RAIN EMISSIONS

This project is directed toward control of NO_x and SO_x emissions from pulverized coal flames by combustion process modifications. It includes fundamental and applied research elements as well as full-scale demonstrations.

CONTRACTS

1. "IEA low NO_x coal combustion agreement"

Canada, under an IEA Agreement with Sweden and Denmark, is co-funding a three phase investigation of staged flames for suppressing NO_x and SO_x during combustion. Phases I and II, now completed, identified the overriding role of fuel nitrogen in producing NO_x emissions and established that burner air staging with limestone injection can be used to reduce substantially acid gas emissions. Stage III, if implemented, will involve validation trials in an operating boiler with a staged burner concept developed by the US Environmental Protection Agency.

2. "CFB Gagetown retrofit burner installation"

A low NO_x/SO_x burner design that has been the subject of intensive research in Europe and the United States is being demonstrated in Eastern Canada. Two burners, each rated at 12 MWt, are retrofitted to a hot water heating boiler and commissioning trials using a 3% sulphur coal are in progress. Preliminary results indicate that NO_x and SO_x emissions have been reduced by 50% with no change in boiler efficiency. Other coals and sorbents will be evaluated during the 1985 and 1986 heating seasons.

Technology Transfer

EMR also contributes to low NO_x/SO_x combustion studies being sponsored by the Canadian Electrical Association, a consortium of electrical utilities. One study, which addresses burner/furnace staging with limestone injection in a 300 MWe, corner-fired boiler, has resulted in SO_x reductions of up to 40% and NO_x reductions of 50% while burning a 0.5% sulphur lignite. The second involves a 6 MWt slagging combustor in which both SO_x and NO_x are prevented from forming in the reducing zone of the multi-staged burner. Trials with a subbituminous coal indicate that more than 60% sulphur capture without limestone addition, and NO_x levels below 150 ppm are achievable.

CARBONIZATION RESEARCH

Canada exports about 16 million tonnes of coal annually, most of which is high-grade coking coals from Western Canada. To provide technical support to Canada's metallurgical coal producers the Energy Research Laboratories continues to provide expertise, laboratory and pilot plant facilities for comprehensive carbonization and cokemaking investigations. CANMET, as a member of the Canadian Carbonization Research Association, provides all experimental facilities and scientific and technical personnel for assisting in planning and carrying out research of immediate interest to both the coal and steel industries. CANMET scientists also plan and conduct in-house and contract research activities often of a more national interest. Carbonization research programs being conducted at ERL are detailed below.

CONVENTIONAL COKEMAKING IN SLOT-TYPE OVENS

The CANMET technical-scale coke ovens are extensively used by the coal and steel industry to evaluate the coking properties of coking coals and blends having potential commercial applications. Results of these coke oven trials are often supplemented by small-scale tests to measure dilatation and by laboratory analyses to determine the chemical, rheological and petrographic properties of both coal and coke.

EFFECT OF BLEND COMPOSITION ON COKE QUALITY AT LONG COKING TIMES

Currently some Canadian steel producers are producing coke using longer than normal coking times because of the decrease in the demand for steel. In this CANMET/CCRA program, a Western Canadian medium-volatile coal was mixed with various proportions of an Appalachian high-volatile/low-volatile blend so as to have five blends having the same average reflectance of 1.26%. Results indicated that the coke ASTM stability improved with longer coking times but ASTM hardness and coke strength after reaction properties (CSR) deteriorated. Incorporation of the medium-volatile Canadian coal improved CSR properties at both boking times tested and reduced coking pressures. ASTM stability and hardness remained unchanged with up to 50% medium-volatile Canadian coal in the blend.

REACTIVITY AND HIGH TEMPERATURE STRENGTH OF COKE

Coke strength after reaction (CSR) and coke reactivity (CRI) have become important parameters to blast furnace operations overseas. CSR and CRI measurements on cokes from several CANMET and CCRA research projects have shown that increased basicity of the coal (or coke) ash increases coke reactivity and lowers CSR; increased ash content lowers CSR; higher inert levels in the coke lowers CSR and increases CRI; carbonization conditions influence CSR and CRI moderately; coal rank has little, if any, influence on CSR or CRI (contrary to other studies); and CSR test is much more rigorous on coke than conditions in a blast furnace. Work on the high temperature testing of cokes and other blast furnace burden material (iron ores) is continuing.

COKE MICROSCOPY FOR COAL CARBONIZATION

During the past year CCRL examined the optical anisotropy of cokes made in its technical-scale ovens in order to improve interpretation of cokemaking research data. Analysis of results of Appalachian and Western Canadian coals showed that the size of the optical anisotropic units formed during the softening of coking coals were similar for each coal type and increased in size as the coal rank increased. Coke texture is largely independent of the coking conditions that can be encountered in slot-type coke ovens and in coal blends the anisotropy types of the individual coals are largely retained as coal interaction is small. Coal oxidation reduces the size of the anisotropic units and addition of pitches may reverse this trend. In poorly coking coals pitches may increase the size of the units or alternatively break-up large units (domain) to intermediately-size units (elongated flow) and greatly improve coke properties. Optical texture analysis is useful for investigating the fate of semi-reactive macerals in coals and for examining the mode of coke degradation in the blast furnace.

ADDITIVES TO COKE OVEN CHARGES

Previous studies have shown that pitch and bitumen-like additives can be added to some high inert coals to improve coke quality. In the past year CCRA/CANMET has extended this study to include blends of poor coking Appalachian and Western Canadian coals containing cheaper additives. Carbonization and coke quality evaluations on these blends, as well as on blends containing CANMET hydrocracked residuals is continuing.

EFFECT OF COAL STORAGE ON COKING COAL PROPERTIES

Twelve drums of one type of Western Canadian coal were divided into nine drums stored at room temperature and three drums stored under refrigeration to determine the effects of time and temperature on thermal rheological and coking parameters. Storage at ambient temperatures caused the Gieseler fluidity and Ruhr dilation to decrease quickly for about 6-8 weeks, then moderately thereafter. Neither storage time nor refrigeration of samples had any significant effects on the cold coke strength properties. However, increased storage time caused coking pressure, coke strength after reaction, and amount of 50-mm coke to decrease. The coke reactivity index and the amount of coke breeze increased as storage time increased.

PRELIMINARY CAGE TEST PROGRAM

ERL evaluated 9 cokes collected from different regions of an industrial coke oven. Coke quality was different for each of the 9 cokes depending upon oven location and the results were sufficiently encouraging to extend the program. In future studies gas pressures and temperatures at the centre of the cages will be obtained. The study will hopefully establish experimental guidelines so that pilot ovens can more closely simulate industrial practices (specific to certain areas of an oven) by reproducing coke quality and coking pressures.

PART III

SYNTHETIC FUELS RESEARCH LABORATORY

HIGHLIGHTS

The Synthetic Fuels Research Laboratory experienced an eventful year of progression of technical and scientific achievements through dedicated in-house activities linked to cooperative efforts with industry, non-profit institutions, provincial agencies and the U.S. Department of Energy.

The AOSTRA/EMR/Industry planning studies for development of an Oil Sand Development Centre have reached the stage where decisions on engineering, procurement and construction can be made. The extent of commitments to be negotiated with industry are the only unresolved factor. The centre is considered to be essential for ensuring industrial acceptance of new generation technology for more efficient and environmentally compatible extraction of bitumen from mined oil sands. If the centre does not materialize, it is anticipated that resources may be reprofiled to support other technology for exploitation of the Athabasca oil sands.

Effective monitoring and control of the thermal and fluid fronts associated with in situ steam injection and combustion processes for recovery of bitumen and heavy oil have been elusive objectives of industry. Many unsuccessful attempts at remote sensing have been made. However, assessment of Canadian and American experience and laboratory studies in the U.S.A., which show that acoustic emissions may be drastically attenuated by temperature in bitumen and heavy oil reservoirs, has led to the initiation of a major monitoring program at the Gregoire Lake In Situ Pilot (GLISP) project in the Athabasca oil sands. The program is a component of bilateral R, D&D with the U.S. Department of Energy which promises significant benefits to all participants.

Construction of the 5000-b/d CANMET hydrocracking upgrader at the Montreal East refinery of Petro-Canada is progressing on schedule. This is a $100 million project with Canadian content of about 90%. The upgrader will be commissioned by July 1985.

The AOSTRA/Industry study of upgrading processes has entered Phase II to plan for feedstock testing of the CANMET, Veba and H-Oil processes. Negotiations are underway between Petro-Canada, AOSTRA and the Province of Québec for construction of a 50-b/d pilot plant in Montreal to be operational in the fall of 1986.

Petro-Canada provides direct support from its own laboratories and has provided 12 PY to complement CANMET's staff in conducting pilot plant runs and research in support of the 5000-b/d upgrader. Eleven 30-day pilot plant runs were completed to establish a sound database for operation of the commercial plant. Considerable progress was achieved in fundamental studies in the areas of additive preparation, product characterization, reactor hydrodynamics and residue utilization.

Coprocessing of coal with bitumen, heavy oil and heavy ends from refineries has been shown at CANMET to offer significant technical and economic advantages over conventional coal liquefaction processes. Moreover, coprocessing is attuned to the Canadian coal and oil resource bases in Alberta, Saskatchewan and Nova Scotia; and, is a natural extension of CANMET hydrocracking technology. CANMET is exercising a leading role in the development of this technology with an intensifying R&D program which will extend into pilot plant operations in mid-1986.

The success of CANMET's nation-wide program of coal conversion R&D was evident at the Second Contractors' Review Meeting, Calgary, November 14-16, 1984. The Sandwell Beak Centrax Process for separation of solids from coal derived liquids, for example, may be critical to any successful direct liquefaction process. Success is also evident from the new ability of Canada to enter into international development programs on a contributing technical and scientific basis.

BITUMEN AND OIL RECOVERY

EXTRACTION OF BITUMEN FROM MINED OIL SANDS

A Phase III engineering and planning study for an Oil Sand Demonstration Centre in the Fort McMurray area has been essentially completed. The study was funded jointly by AOSTRA, as the operator, with Chevron, Nova, Shell, Petro-Canada and EMR. The proposed site is on Chevron's lease adjacent to Syncrude. The proposed centre, to provide core facilities for demonstration of extraction processes in the range of 20 to 100 t/h, depending on the process, would cost about $22 million. The Taciuk/UMATAC process has been identified as the first process to be demonstrated. Negotiations are under way to commit the support from industry which is mandatory to supplement the commitments of AOSTRA and EMR before the engineering/procurement/construction stage can be implemented. EMR's commitment is subject necessarily to joint venture support being achieved within a limited time. Otherwise, the available funds will have to be reallocated to other high priority R, D&D.

IN SITU RECOVERY OF BITUMEN AND HEAVY OIL

The announced expansion of pilot in situ thermal recovery projects to commercial scale by Esso, BP/Petro-Canada, Suncor and Amoco in the Cold Lake area, Shell in the Peace River area and Husky in the Lloydminster area will have total production capacity of well over 100 000 b/d by 1990. To maintain this momentum, continued research is essential to improve existing technology and develop new technology, particularly, with emphasis on applications to the Athabasca area and to marginal reservoirs. CANMET plays a role in support of critical gap and long range research, primarily via contracts.

Successful design and operation of in situ pilots is reliant, to an important extent, on physical and numerical simulation to evaluate process options and interpret field performance. The University of Alberta is using a low-pressure scaled physical simulator to investigate novel concepts for application of steam injection processes to marginal reservoirs in Alberta and Saskatchewan. The University of Toronto is developing more cost effective and efficient methodology for dynamic grid numerical simulators with special application to horizontal well concepts of oil recovery. In-house, a novel technique is being developed for rapid yet discriminating evaluation of water soluble additives to steam.

Under a bilateral agreement with Canada, the US Department of Energy has funded the screening of a wide range of additives for improving the effectiveness of oil recovery. A complementary program is being developed for implementation in Canada. Steam additives have potential for not only increasing the recovery efficiency but also, and perhaps more importantly, increasing significantly the rate of production. The latter is an important economic factor.

Also under bilateral agreement with the US, Canada has initiated a field project which will assess and develop technology and Canadian capability to monitor thermal and fluid frontal movements which proceed from injection to productions wells. Currently, realtime monitoring and control depends on unreliable inference. The program involves high resolution active and passive 3-D seismic imaging, short baseline vertical seismic profiling, investigative tomography and precise surface levelling to be correlated with data from observation wells and production data.

Cost-shared R&D at Gulf Research Canada is progressing on schedule with investigation of factors which affect the thermodynamics and kinetics of fuel laydown during in situ combustion processes; and, both the potential and the operative mechanisms of using caustic surfactants to enhance the waterflood recovery of heavy oil in marginal reservoirs.

Steam injection projects use the thermal equivalent of about one third of the produced bitumen or heavy oil. Currently, natural gas is used in Western Canada. In the medium to long term, wet oxidation of byproduct upgrader residues, problem emulsions and low-grade coal along with untreated field-produced waters may be attractive. The Ontario Research Foundation under contract to EMR, has applied for patent coverage for high, as opposed to conventional low, thermal flux wet oxidation reactors which conceptually have potential application in oilfield operations.

DEVELOPMENT OF UPGRADING TECHNOLOGIES FOR BITUMEN, HEAVY OIL AND RESIDUALS

PILOT PLANT WORK IN SUPPORT OF CANMET HYDROCRACKING COMMERCIALIZATION

Eleven pilot plant experiments of 30 days duration each were carried out in support of the demonstration plant which is due to commence commissioning tests in mid-1985. The work involved optimization of process conditions and characterization of new feedstocks. Details of the work performed in this area are confidential and are on file at the Energy Research Laboratories.

FUNDAMENTAL STUDIES AND PROCESS DEVELOPMENT FOR UPGRADING OF BITUMEN AND HEAVY OIL

Detailed characterization of solid samples from the hydrocracking pilot plant was carried out for each run. Techniques included microscopic examination and particle size measurement. These results were then correlated with processability for different feeds and operating conditions.

In order to identify factors which affect additive activity and to develop standard procedures for additive characterization, detailed studies using optical and electron microscopy and Moessbauer spectroscopy were performed.

The influence of coal rank on additive activity was investigated by means of autoclave experiments, and a number of different coals were identified as potential additive bases. Several alternate additive preparation schemes were investigated, and several new types of additives were studied using a batch autoclave. This work has identified promising areas for future research. A program to study the use of various wastes as potential hydrocracking additives is underway.

Various NMR and other spectroscopic techniques in the study of hydrocracking processes are being assessed. Of particular interest is the use of solid NMR techniques to study solid carbonaceous phases present at various stages of upgrading processes.

A number of instruments were assessed in detail for ERL's NMR facility. This involved running selected samples on the NMR instruments and determining whether the results met ERL's requirements. A suitable instrument has now been purchased and delivered.

A number of test runs were performed on the new continuous bench-scale unit. The yields and conversions obtained so far are consistent with pilot plant data. Equipment problems prevented running in a fully unattended mode, however these problems are being corrected.

In order to study coking processes under typical reaction conditions, an optical microscope high pressure hot stage was installed and is scheduled for commissioning during the first quarter of 1985/86.

Experiments to determine the effect of oxidation on coal properties and on mesophase formation from hydrogenation of coal were carried out and a correlation of the degree of coal oxidation on reflectance and microhardness was completed. Petrographic studies of coke samples from a contract study of the kinetics of coking of heavy oil and bitumen were commenced.

As part of a study of new upgrading schemes, the application of ultrasound is being investigated. A high pressure high temperature autoclave system for ultrasonic irradiation of mixtures of heavy oils and hydrogen was designed, and a sonicator was acquired to carry out preliminary tests.

The commissioning of a gamma-ray scanner was completed. Studies of the hydrodynamic behaviour of hydrogen/heavy gas oil and of hydrogen/pitch two-phase systems at elevated temperatures and pressures were carried out. The scanner was also used to monitor pilot plant runs.

CONTRACTS

1. "Gamma ray densitometry"

A method using a single radioisotope was developed to measure the H/C ratios for pure hydrocarbon compounds. Following EMR's suggestion this method was also used to measure the ash concentration in pilot plant reactor samples. A good correlation was found with the standard ash analysis technique. This method promises to be very useful for rapid off-line measurements of hydrocracking process streams and other similar industrial applications. As part of the same contract the feasibility of using tomographic methods for multi-phase flow was studied and the use of radioisotopes for residence time distribution was also examined.

2. "Cold reactor modelling"

The effect on gas hold-up, solids dispersion coefficient and solids concentration profiles of gas and liquid properties and sparger design was measured in a three-phase tubular bubble column. General correlations were developed to describe gas hold-up and solids dispersion. These correlations covered a wider range of gas and fluid properties than previous studies. The results indicated the need to obtain more detailed knowledge of solids mixing in turbulent bubble columns and of the effect of column diameter on liquid/solids mixing. To address the latter, a 60-cm column was installed and experiments will be carried out in the second phase of this contract during 1985/86.

3. "Effect of oxidation on coke formation from coal and heavy oil"

As an extension of a previous contract study, autoclave experiments were performed to study the effect of coal treatment on hydrocracking of heavy oil.

4. "Flash hydropyrolysis of pitch"

A study was completed to test the feasibility of converting hydrocracked pitch using flash hydropyrolysis.

5. "Kinetic studies of coke formation" - Phase II

As a continuation of a previous contract, experiments to determine the effect of sulphur on the kinetics of coke formation from separated heavy oil fractions were performed. A micro-autoclave system was also designed and installed to enable kinetic studies to be performed under hydrogen at high pressure. Experiments are scheduled for completion in 1985/86.

6. "High temperature EPR studies of heavy oil"

A contract to study the type of free radical formed in heavy oil and separated components at high temperature under hydrogen and nitrogen atmospheres using electron paramagnetic resonance was commenced and is due for completion in the first quarter of 1985/86. An increase in radical concentration with temperature was observed whereas the concentrations were dependent on the component investigated at a given temperature. Experiments are underway to identify the radicals using spin-trap techniques.

COAL LIQUEFACTION

COPROCESSING RESEARCH AND DEVELOPMENT

This project consists of a fundamental research program on the simultaneous upgrading of coal and bitumen, heavy oil or residuals. The coprocessing concept has stimulated a great deal of national interest. In Western Canada, the low-rank coals of Alberta and Saskatchewan can be combined with tar sand bitumens or heavy oils to form coprocessing feedstocks. In Eastern Canada, Nova Scotia coals have potential as feedstocks for coprocessing when combined with conventional crude residuals.

An extensive research program on coprocessing is being carried out in the Coal Liquefaction Section of SFRL. The in-house program includes bench-scale continuous-flow single-stage and two-stage experiments; micro batch autoclave experiments and characterization of coprocessing liquid and solid products. Other aspects of this project are also being addressed through a contract program.

EXPERIMENTAL PROGRAM

Coprocessing of Low- and High-Rank Coals in Heavy Oil Solvents

A report was completed on the effect of the coprocessing medium on product yields and quality. A comparison of the performance of several media was presented with recommendations regarding the optimal medium for subbituminous coals.

A status report on CANMET coprocessing was completed. The report contains an interesting comparison between coal liquefaction, coprocessing and hydrocracking as upgrading alternatives. It also contains results of the effect of coal concentration on coprocessing behaviour with emphasis on the nature of any synergism existing between the coal and the heavy oil.

A study on the effect of coal rank on coprocessing behaviour was completed and a report is under review.

An investigation of the coprocessing behaviour of high-volatile bituminous Eastern coal was initiated. Experiments are being carried out using petroleum residues as media.

Continuous-flow bench-scale experiments to study the effect of H_2S as a coprocessing promoter are under way. The objective of the study is to confirm the effects of H_2S observed in batch autoclave experiments.

Two-Stage Coprocessing

A series of experimental runs was carried out in a newly commissioned two-stage tubular reactor unit using vacuum bottoms and subbituminous C coal feedstock. Operating conditions in the first stage are milder than those in the second.

Characterization of Coprocessing Liquid Products

Preparative liquid chromatography and analytical HPLC were applied for quantitative analysis of coprocessing liquid products. Using an analytical amino-cyano column, liquid products (205-525°C) were separated into saturates, olefins, aromatics and polars. Calibration standards were obtained from a standard continuous run using a preparative NH_2 column. This quantitative method for hydrocarbon type analysis was compared with gravimetric measurements of each hydrocarbon type using a semi-preparative amino-cyano column.

Coal Solubilization in Heavy Oils/Bitumen

The solubilization of subbituminous coal in a variety of petroleum residues and a bitumen vacuum bottoms was investigated. Coal conversions were investigated using a batch micro-autoclave unit at short reaction times and moderate temperatures. In general, in terms of coal solubilization bitumen vacuum bottoms behaved similarly to petroleum residues. Coke formation was studied as a function of residence temperature by petrographic analyses of the THF insolubles. At short residence times, the treatment of subbituminous coal with a good hydrogen donor solvent such as tetralin was compared with the use of bitumen or heavy oil solvents.

CONTRACT

1. "Evaluation of the Sandwell Centrax Process for the separation of solids and recovery of liquids from coprocessing slurry samples"

The objective of this contract with Sandwell Technologies was to apply the Centrax process to coprocessing products. Preliminary analysis of the data shows that the process is essentially feasible. It was found that for typical coprocessing samples, careful selection of the extractant is needed to avoid partial precipitation of residual liquids.

CONSTRUCTION OF COAL/HEAVY OIL COPROCESSING PILOT PLANT

A pilot plant to assess the upgrading of coal/heavy oil slurries is being constructed by the Process Development Section. A contract was let to Partec-Lavalin to produce detailed process flow diagrams, piping and instrumentation drawings and detailed layout plans. This stage is now complete. From the layout drawings the support structures for the pilot plant are being designed and constructed and should be in place by the second quarter of 1985/86. In order to use the location chosen for the plant, it is necessary to modify the hydrogen supply system for the two existing hydrocracking pilot plants in order to remove the hydrogen compressors and large compression vessels from this location. The new hydrogen compressors, mass flow meters and outside storage vessels required for this new system have been delivered. The best location for the hydrogen compressors is in a room presently occupied by the emergency electrical generator, however this is being replaced by a much larger unit to be located outside the building. This room will therefore be available when the new unit arrives.

It is planned to have the hydrogen supply system completed by about mid-1985 provided the new generator arrives on time. The mass flow meters for measurement of hydrogen consumption have already been installed in both pilot plants for thorough testing with the existing hydrogen supply system before the new system is installed.

The slurry feed system for the new pilot plant will be located in the room occupied by a hydrogen supply bell and hydrogen generator (electrolyser). The bell will no longer be used after the new hydrogen supply system has been installed; the electrolyser is not used at all since changing to an outside supply of hydrogen. After these units are disposed, structural supports will be installed for the slurry feed system. Since this unit will be placed some distance away from the remainder of the pilot plant, it will be necessary to have a long recirculation loop from the feed tanks to the high pressure feed pumps. Therefore, lines and pumps are being properly sized to ensure that the feed system can satisfactorily handle the viscous coal slurries.

The process control and data acquisition system to be used for all of the section's pilot plant facilities has been installed and tested on both pilot plants. The coprocessing pilot plant will be tied into this when completed.

ADVANCED COAL LIQUEFACTION AND PYROLYSIS PROCESSES FOR CANADIAN COALS

Direct coal liquefaction technology offers a means of providing alternative liquid fuels to meet future Canadian needs. CANMET has supported a national contracting program on direct coal liquefaction. Under this program there is participation from the east to west coast. Projects, either starting or ongoing, address direct hydroliquefaction of low and high-rank Canadian coals, the petrography of parent coals and liquefaction residues, and other processing and fundamental research areas. This contract program draws upon a wide cross-section of ERL staff for scientific authority duties.

Flash pyrolysis is an alternative route to coal-derived liquids. Although in an earlier stage of development, the approach has potential to skim selected coal fractions as liquid hydrocarbons before combustion of the remaining char. CANMET is funding a number of projects under contract to develop Canadian flash pyrolysis and flash hydropyrolysis technologies.

CONTRACTS

1. "Application of solvent-salt liquid clathrate system to coal liquefaction"

In the second phase of this contract, it was established that aromatic solvent-salt phases, known as liquid clathrates behave as strong solvents for coal extraction, i.e., they are physical solvents. At atmospheric pressures and 80°C, conversions as high as 22 wt % for Eastern, and slightly lower for Western Canadian coals were obtained. Attempts at in situ upgrading by incorporating a transition metal into clathrate layers and performing the extraction at 180°C and 3500 kPa resulted in an increase in coal conversion to 30 wt %.

2. "Characterization of solid residues from coal liquefaction processes"

This contract provides petrographic analyses of coal feedstocks and solid residues from coal liquefaction and coal-bitumen coprocessing experiments. Descriptive and analytical reports were prepared for 137 samples from seven CANMET projects. This year saw a greater interaction between the petrographers and CANMET scientists, engineers and contractors because of a new interim reporting system and because the petrographers took field trips to meet with the contractors. The petrographers also participated in the CANMET Coal Conversion Contractors' Review Meeting in Calgary.

A new feature introduced in 1984/85 was the separation and density determination of macerals from selected Canadian coals. The results will be used to improve the quantitative reliability of the petrographic analysis, particularly as it relates to the degree of coal conversion. It marks the beginning of an attempt to establish a truly Canadian version of the (Australian) Petrofactor parameter for determining the liquefaction potential of Canadian coals. This work was also done to support the unique system of nomenclature for analyzing liquefaction residues developed by the petrographers during this contract.

Analysis of a large suite of samples from continuous single-stage catalytic hydrogenation and two-stage liquefaction tests at the Nova Scotia Research Foundation revealed trends related to both the nature of the coal feedstock and the operating conditions.

The way coal conversion is initiated was studied using residues from the initial stages of reaction. These short contact time autoclave experiments help establish the coal-bitumen interactions that make this processing mode successful.

In-house experiments using a continuous reactor generated samples from the coprocessing of coals of different ranks. Correlating the residue analyses with the parent coal's properties, the type and amount of catalyst, and the operating variables provides a higher degree of consistency and more confidence in the pilot plant results.

The residues from two-stage continuous coprocessing were similarly analyzed quantitatively in terms of unreacted coal, altered coal, and coke formed during processing to give a more refined interpretation of the yields.

3. "Direct liquefaction of Nova Scotia Coals", Phase VI

The Nova Scotia Research Foundation has completed a series of experimental studies of direct single-stage liquefaction. The final phase used catalysis under severe operating conditions. Quantitative results from statistically designed and analyzed runs in the continuous liquefaction pilot plant showed that yield of distillable products is dependent on the feedstock. None of the Nova Scotia coals was as easy to convert as Illinois No 6. It was concluded that two-stage coal liquefaction must be investigated. Currently a contract, funded by EMR and the Nova Scotia Department of Mines and Energy, provides for modification to the pilot plant and evaluation of the potential of two-stage direct liquefaction for Nova Scotia.

4. "Continuation of the evaluation of Hat Creek coal for coal liquefaction"

The evaluation of Hat Creek coal for direct liquefaction using a continuous flow bench scale unit was undertaken. The final report on the first phase of this study was completed. It was found that using recycle donor solvent, Hat Creek coal gives high total conversion (90%) in a single-stage continuous operation. The primary coal liquid products can be hydrotreated to generate naphtha and recycle donor solvent using a continuous fixed bed catalytic hydrotreater. The bottoms fraction of the primary liquid product can be recycled to liquefaction and are effectively upgraded. The current phase of the contract addresses other aspects of the process such as detailed material balance closures on the liquefaction and hydrotreater units, stability of THF as a separation solvent, net product optimization, product compatibility for a specific end use, waste disposal options and economic analysis of the process.

5. "Evaluation of the integration of the Sandwell Centrax process into an integrated two-stage liquefaction process"

Phase I: The objective of this phase was to investigate the feasibility of integrating Centrax into a two-stage liquefaction process as an interstage solids removal and product recovery step. Samples provided by E.P.R.I. were tested at the bench scale in terms of coal recovery and overall process energy requirements. Centrax process flowsheets were generated to illustrate a typical two-stage application based on the Wilsonville Project.

Phase II: The objective of this phase was to design, fabricate and commission a novel prototype Centrax separator. Design specifications and concepts were developed and a detailed engineering design of a single-stage unit was completed. The unit was constructed and then commissioned using typical feedstocks.

Phase III: The objective of this phase was to advance the development of the Centrax process by demonstrating operation of the new prototype separator and performing overall material and energy balances to obtain better estimates of the economics of operation in a two-stage liquefaction mode.

6. "Techno-economic comparison of the Sandwell Centrax solid-liquid separation process with Kerr-McGee critical solvent deashing process as part of an integrated two-stage liquefaction process"

This project will provide a techno-economic assessment of the Sandwell Centrax solid/liquid separation process applied as a separation technique in an integrated two-stage coal liquefaction process. It involves reviewing proprietary data supplied by Sandwell and critically evaluating the performance of the Centrax process compared with the Kerr-McGee critical solvent deashing (CSD) process. The study will help identify unresolved technical problems, research needs and difficulties of scale-up for the process.

7. "Critical evaluation of the hardware development for the Sandwell Centrax process"

The main objective of this contract was to evaluate the mechanical design, theory and fundamental operation of the Centrax separator and to help identify technical uncertainties related to time and costs for scale-up.

8. "Lignite beneficiation as an integral part of a direct liquefaction process"

A contract was awarded to the SNC - Ontario Ministry of Energy to investigate the use of spherical oil agglomeration in the beneficiation of low-rank Canadian coals as an integral part of a direct liquefaction process. The use of oil agglomeration in this instance avoids many of the high costs normally associated with this method of coal beneficiation since the oil for agglomeration is provided by the liquefaction process and is simply recycled through the plant. The contract is expected to be completed in 1985 and if the process proves successful it could have an important impact on developing Canada's low-rank coal reserves for liquefaction. The major hurdle is to develop a way to change the natural hydrophilic properties of low-rank coals in order to make them amenable to processing by oil agglomeration. Preliminary studies with anthracene oil (as a model oil) have been undertaken to provide the basis for further tests using a true process-derived oil.

9. "Evaluation of a flash pyrolysis process applicable to Canadian coals"

The objective of this phase of the flash pyrolysis project with the University of Waterloo was to investigate more process alternatives to give improved liquid yields and to select processing schemes that appear to be optimal for Canadian coals. One of the process alternatives was acid prewashing. It was found that, for low-rank coals, a significant increase in liquid yields occurs when the coals are treated with acids prior to processing. The effect is not as significant for higher rank coals. Detailed studies on the effect of pyrolysis atmosphere on acid washed coals and of scale up effects are being conducted.

10. "The CANMET coal flash pyrolysis project"

CANMET's 1 kg/h flash hydropyrolysis unit was commissioned at the end of 1983 at the premises of Ontario Research Foundation (ORF) in Mississauga. A preliminary series of experiments was carried out with the unit in the first part of 1984, and two contracts for the operation of the unit were initiated by ORF in 1984/85.

The preliminary series of runs provided information on the processing of Forestburg subbituminous coal and to suggest refinements to the system and its operation. A more extensive experimental program is under way using Forestburg coal and Nova Scotia hv bituminous coals. CANMET process pitch was also run, but this material proved unsuitable to the unit.

ANALYTICAL SECTION

The Analytical Section provides analytical services to ERL for petroleum and petroleum type products used and generated in the research pilot plants. Products range from bitumens and heavy oil residual fractions to light distillates, naphthas and hydrogenation product gases. Analyses are done in three general areas:

(a) elemental analysis (C, H, N, O, S, and metals),
(b) standard product tests as performed routinely in industry, e.g., ASTM test methods and
(c) chemical component analysis, e.g., GC, GC/MS, NMR.

SUMMARY

For the calendar year 1984, the Analytical Section performed and reported some 19 000 analyses on approximately 5800 samples. Most of the work was carried out in direct support of ERL in-house research projects. About 8% was conducted under collaborative interlaboratory programs and for outside clients such as government departments, universities and research laboratories.

IN-HOUSE RESEARCH PROJECTS

Most of the section's work involved analytical support of bitumen processing (65%) with most of that effort to satisfy the requirements of the CANMET hydrocracking pilot plant (50%) and the rest to research in catalytic hydroprocessing and characterization of bitumens and distillate products (15%).

The coal research programs received 25% of the section's efforts, essentially in support of research in coal liquefaction. The CCRL research programs required 2% of the section's efforts.

OUTSIDE ACTIVITIES

An important part of the Analytical Section's efforts involve collaboration in interlaboratory testing programs. These programs are necessary to maintain a high quality in the precision and accuracy of the analyses performed by the laboratory. The section collaborates in the CGSB Cooperative Fuels and Lubricants Exchange and in other interlaboratory programs. In 1984 the section participated in an international exchange of heavy oils, an exchange of hydrocracking pilot plant samples with Petro-Canada in support of the CANMET hydrocracking demonstration project and an exchange of crude oil samples between Montreal area petroleum laboratories.

Analyses were performed for a number of outside clients, mainly CANMET's Mining Research Laboratories, government departments and Crown corporations (NRC, DND, DPW, Environment Canada, Consumer & Corporate Affairs, etc.) and for the New Brunswick Electric Power Commission under the terms of the contract with NBEPC. These activities represented about 8% of the section's output.

NEW DEVELOPMENTS 1984

During 1984 new instruments were obtained for the analysis of ultralow sulphur levels in naphthas and distillates and C, H, N. These instruments extended the section's capabilities to perform elemental analysis more efficiently and at lower levels. Quality assurance projects dealing with elemental analysis showed that results provided to ERL researchers were of excellent quality.

New NMR and GC instruments were also obtained. These instruments will be brought into service in 1985 and will improve significantly the section's analytical capabilities in the area of chemical analysis. Procurement was also finalized for a computerized data management system. The acquisition of this system in 1985 will help manage more effectively the large amounts of analytical information.

A research contract was awarded for the development of a rapid GC/MS method for the determination of various saturate and aromatic hydrocarbons in petroleum fractions ranging from naphthas to heavy gas oils. This method is to support research in upgrading of synthetic crudes.

TRAINING

Section personnel participated in a total of 61 days of training in 1984 in the areas of laboratory safety and first aid, distillation of petroleum products, and gas chromatography and GC/MS.

ANALYTICAL SERVICES/BREAKDOWN BY CLIENT - 1984

Client	No. of Samples	No. of Tests	Cost ($K)
Synthetic Fuels Research Laboratory			
Process Development Section	2 122	10 152	278.8
Coal Liquefaction Section	1 773	3 929	141.6
Analytical Section Collaborative Tests	70	252	5.7
Hydrocarbon Processing Research Laboratory	1 369	2 983	86.2
Combustion and Carbonization Research Laboratory	127	383	10.9
Mining Research Laboratories	34	74	1.6
New Brunswick Electric Power Commission	42	594	10.5
Others (government departments, universities, etc.)	334	873	25.0
TOTAL	$5 871	$19 240	$560.3

ENGINEERING DESIGN AND SUPPORT SERVICES

SUMMARY

Engineering design, equipment development and information services were provided to all areas of the division.

The equipment development shop completed 125 assignments requested by ERL as well as Mining Research Laboratories. Most were of an urgent nature for repairs and modifications to experimental and prototype equipment.

Forty-four projects were identified which required discussions and subsequent planning with Public Works Canada. The following major items were initiated during 1984/85:

- design for renovations to Bldg. 7
- design of mezzanine and laboratory in Bldg. 6
- design of compressor and sample rooms in Bldg. 6
- design of mezzanine and control room in Bldg. 5
- procurement and installation of 400-kW emergency generator in Bldg. 4
- initiation of design for alterations in Bldg. 4 for a new pilot plant and feed system
- renovations to rooms B10 and B11 in Bldg. 3 to accommodate a scanning Auger microscope
- initiation of design for alterations to rooms 120 and 121, Bldg. 2 for the circulating fluidized bed combustor and ancillaries.

The information services arm performed literary editing of all division reports, provided information services, organized numerous tours of the facilities and was responsible for compiling and editing the division's 1984/85 annual report.

APPENDIX A

PROFESSIONAL, TECHNICAL AND SUPPORT STAFF

PROFESSIONAL, TECHNICAL AND SUPPORT STAFF

Name	Degrees and Diplomas	Occupational Category
B.I. Parsons	B.Sc., Ph.D. (McGill), D.Phil. (Oxford)	Director of Laboratories
G.D. Brown		Secretary

Administrative Services

Name	Degrees and Diplomas	Occupational Category
L. Patrick		Administrative Officer
A. Baldock		Clerk
E. Bonvie		Clerk
M. Grebenc		Clerk
J. Hogan (Term)		Clerk
P.M. Hughes		Clerk
D. Millar		Clerk
M. Roy (Switchboard Operator)		Clerk
A. Splett		Clerk
L. Forieri		Receiver/Warehouse
B. Vincent		Clerk
J. Boudreau (Term)		Secretary
D. Deans (Term)		Secretary
S. Gilmour		Secretary
J. Haw		Secretary
M.E. Turner		Secretary
G. McCallum (Term)		Secretary

Engineering Services

Name	Degrees and Diplomas	Occupational Category
L.P. Mysak	Dipl.Mech.Tech. (Algonquin), B.A.Sc., M.Eng., P.Eng. (Ottawa)	Engineer
D.M. Arsenault		Millwright
J.M. Dowdall		Machinist
J.L. Harcourt		Information Officer

SYNTHETIC FUELS RESEARCH LABORATORY

Name	Degrees and Diplomas	Occupational Category
J.M. Denis	B.A.Sc. (Ottawa), P.Eng.	Manager

Process Development

Name	Degrees and Diplomas	Occupational Category
D.J. Patmore	B.Sc. (Bristol), Ph.D. (Alberta)	Res. Sci.
T.J.W. de Bruijn	B.Sc., M.Sc., Ph.D. (Delft)	Res. Sci.
J. Chase	B.Sc.Chem. (Acadia), B.Sc. Chem.Eng. (McGill) Ph.D. (Univ. of London)	Res. Sci.
W.H. Dawson	B.Sc. (McGill), Ph.D. (Western Ontario)	Res. Sci.
D.D.S. Liu	B.Chem.Eng. (N.Taiwan Univer.), Ph.D. (Dalhousie)	Res. Sci.

Process Development (cont'd)

F.T.T. Ng	B.Sc. (Hong Kong), M.Sc., Ph.D. (British Columbia)	Res. Sci.
R.B. Logie	B.Sc. (New Brunswick), P.Eng.	Engineer
P.L. Sears	M.A., Ph.D. (Cambridge)	Res. Sci.

R.W. Beer		Technologist
A.J.G. Cooke	Dipl. Mech. Tech. (Algonquin)	Technologist
R.W. Devlin	Dipl. Forestry (Sault Ste Marie)	Technologist
G.H. Dicks	Dipl. Biochem. Tech. (Algonquin)	Technologist
R.S. Eagleson		Technologist
A.J. Kuiper	Dipl. Biochem. Tech. (Algonquin)	Technologist
P.E. Landry	Dipl. Mech. Tech. (Algonquin)	Technologist
J. Letourneau	Dipl. Ind. Chem. Tech. (Hull)	Technologist
R.N.L. Lycette		Technologist
G.J. McColgan	Dipl. Journalism (Algonquin)	Technologist
C.A.W. McNabb	Dipl. Mech. Tech. (Algonquin)	Technologist
P.J. Mulvihill	Dipl. Ind. Chem. (Algonquin)	Technologist
G.J. Noel	Dipl. Ind. Chem. Tech. (Hull)	Technologist
V.R. Phillips	Dipl. Mech. Tech. (Algonquin)	Technologist
M.P. Pleet		Technologist
R.A. St. Louis	B.Sc. (Ottawa)	Technologist

Bitumen/Oil Recovery

D.K. Faurschou	B.A.Sc. (Toronto)	Res. Sci.
J. Margeson	B.Sc. (Carleton), M.Sc. (Ottawa)	Res. Sci.

Analytical Section

R.J. Lafleur	B.A.Sc. (Waterloo), M.Sc. (Alberta), P.Eng.	Chemist
D.M. Clugston	B.Sc., Ph.D. (McMaster)	Chemist
V. Whelan	B.Sc. (Waterloo)	Chemist

L. Brazeau	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
D.J.A. Dion	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
P.M. French	Dipl. Chem. Tech. (St. Lawrence)	Technologist
B. Grossman	Dipl. Chem. Tech. (Algonquin)	Technologist
K.M. Hollington	Dipl. Chem. Tech. (Algonquin)	Technologist
G. Kodybka	Dipl. Chem. Tech. (Algonquin)	Technologist
E. Kowalchuk		Technologist
S. Laplante	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
G.R. Lett	Dipl. Chem. Tech. (Algonquin)	Technologist
R.E. Dureau	Dipl. Chem. Tech. (Algonquin)	Technologist
N.R. McLean	B.Sc. (Concordia)	Technologist
D. Whitehead		Technologist
I. Clelland	(Petro-Canada employee)	Technologist
G. MacDonald	(Petro-Canada employee)	Technologist
G. Drapeau	(Co-op student, Sherbrooke)	Technologist

Coal Liquefaction

J.F. Kelly	B.Eng., Ph.D. (McGill) P.Eng.	Res. Sci.
S.A. Fouda	B.Eng. (Cairo), M.A.Sc., Ph.D. (Waterloo)	Res. Sci.
M. Ikura	B.Eng. (Himeji), M.Eng. (Osaka), Ph.D. (McGill)	Res. Sci.
P. Rahimi	B.Sc. (Iran), M.Sc. (Brock), Ph.D. (Alberta)	Res. Sci.
A.D. Agnew		Technologist
R.F. Campbell		Technologist
B.M. Dick		Technologist
J.E. Whiten		Technologist

COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

G.K. Lee	B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.	Manager

Coal Treatment and Coke Processing

T.A. Lloyd	B.Sc. (Carleton)	Phys. Sci.
R.G. Fouhse	B.Sc. (Saskatchewan), P.Eng.	Engineer
P.A. Couturier		Technologist
R.K. Graham		Technologist
P. Malaiyandi		Technologist
J.W. St. James	Dipl. Chem. Tech. (Algonquin)	Technologist
R.R. Bell		Coke Oven Tech.
R.F. Dowdall		Coke Oven Tech.
D.S. Ketchum		Coke Oven Tech.
V. O'Connor		Coke Oven Tech.

Carbonization Research

J.T. Price	B.Sc. (Calgary), Ph.D. (Western Ontario)	Res. Sci.
J.F. Gransden	B.Sc. (London), A.R.S.M., Ph.D. (Western Ontario)	Res. Sci.
J.G. Jorgensen	B.Sc. (Carleton)	Phys. Sci.
M.J. Boyle	Dipl. Mech. Tech. (Algonquin)	Technologist
D.D. Cameron	Dipl. Mech. Eng. (Ryerson)	Technologist
K.F. Hampel	Dipl. Ind. Chem. (Algonquin)	Technologist
M.J. Malette		Technologist
N.R. Manery	Dipl. Min. Tech. (Ste Claire)	Technologist
N.J. Ramey	Dipl. Min. Tech. (Haileybury)	Technologist

Energy Conservation Technology

A.C.S. Hayden	B.Eng., M.Eng. (Carleton), P.Eng.	Res. Sci.
S.W. Lee	B.Sc. (Rangoon), Ph.D. (McMaster)	Res. Sci.
R.W. Braaten	B.Eng. (Carleton), P.Eng.	Phys. Sci.
F. Preto	B.A.Sc. (Toronto), Ph.D. (Queen's)	Res. Sci.

Energy Conservation Technology (cont'd)

D.E. Barker		Technologist
J.M. MacDonald	B.A. (Trent)	Technologist
D.C. Post		Technologist
H.P. Raghunandan	Dipl. Mech. Tech. (Algonquin)	Technologist
T.G. Sellers		Technologist
R.J. Lacelle		Elec. Tech.

Emerging Energy Utilization Systems

F.D. Friedrich	B.Sc. (Saskatchewan), M.Sc. (Queen's), P.Eng.	Res. Sci.
E.J. Anthony	B.Sc., B.A. (open university) Ph.D. (Swansea), C.Chem.	Res. Sci.
D.L. Desai	B.E. (Sardar Patel), M.Eng. (Ottawa), P.Eng.	Engineer
I.T. Lau	B.Sc. (Cmengkunk), M.A.Sc. (Ottawa)	Engineer
V.V. Razbin	Dipl.Eng. (Higher Mechanical-Electrical Institute, Sofia, Bulgaria)	Engineer
W.J. Birtch		Technologist
D.H.J. McLaughlin		Technologist

Industrial Combustion Processes

H. Whaley	B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.	Res. Sci.
G.N. Banks	B.A. (British Columbia)	Res. Sci.
P.M.J. Hughes	B.Sc. (Waterloo) M.Sc. Mech.Eng. (Waterloo)	Res. Sci.
K.V. Thambimuthu	B.Sc. (Birmingham), M.Eng. (McGill), Ph.D. (Cambridge), C.Eng.	Res. Sci.
B. Cox	B.App.Sci. (Ottawa), Mech.Tech. (Algonquin)	Engineer
J.K.L. Wong	B.Sc. (Calgary)	Phys. Sci.
D.E. Friedrich		Technologist
C.J. Hughes	B.A. (Carleton)	Technologist
B.C. Post		Technologist
A. Salamon		Technologist
D.G. Savignac	Dipl.Mech.Tech. (Algonquin)	Technologist

Coal and Coke Constitution

B.N. Nandi	B.Sc., M.Sc. (Calcutta), Dr.Eng. (Karlsruhe)	Res. Sci.
J.A. MacPhee	B.Sc. (St. Francis Xavier), Ph.D. (British Columbia)	Res. Sci.
L.A. Ciavaglia	B.Eng. (Carleton)	Phys. Sci.
B.H. Moffatt		Technologist
S.E. Nixon		Technologist

Project Monitoring and Engineering Design

S.I. Steindl	Dipl.Eng. (Budapest), M.Sc. (Queen's), P.Eng.	Engineer

Quality Assurance

R. Prokopuk	B.Sc. (Alberta)	Phys. Sci.
R.K. Jeffery		Technologist
F.L. Wigglesworth		Elec. Tech.

HYDROCARBON PROCESSING RESEARCH LABORATORY

M. Ternan	B.A.Sc. (British Columbia), Ph.D. (McGill), P.Eng.	Manager

Hydrocarbon Conversion

D.P.C. Fung	B.Sc. (British Columbia), Ph.D. (Windsor)	Res. Sci.
M. Skubnik	B.Eng., M.Eng. (Bratislava), P.Eng.	Phys. Sci.

Pyrolysis and Gasification

E. Furimsky	Dipl.Eng. (Prague), Ph.D. (Ottawa)	Res. Sci.
P.S. Soutar		Technologist
M.W. Channing	Dipl. Forest. Tech. (Sir Sanford Fleming)	Technologist

Analysis and Standardization

L.C.G. Janke	B.Sc. (Sir Wilfred Laurier), B.Ed. (Queen's)	Phys. Sci.
M.D. Farrell	B.Sc. (Carleton)	Phys. Sci.
J.Z. Skulski	Chem. Eng. (Wroclaw, Poland)	Chemist
J. Glasa	Cert.Matric (Bratislava)	Technologist
T.G. Moher	Dipl. Chem. Tech. (Algonquin)	Technologist
T. Psutka	B.Sc. (Carleton)	Technologist
A. Martineau	Dipl. Chem. Tech. (Algonquin)	Technologist
P. Mallard	B.Chem. Eng. (McMaster)	Technologist
H. Koethe	B.Sc. (Honours) (Queen's)	Technologist
P. Zourdos	Dipl. Chem. Tech. (Algonquin)	Technologist

Separation and Characterization Section

H. Sawatzky	B.S.A., M.S.A., Ph.D. (Toronto)	Res. Sci.
M.A. Poirier	B.Sc., M.Sc., Ph.D. (Montreal)	Res. Sci.
S. Coulombe	D.E.C., B.Sc., Ph.D. (Montreal)	Res. Sci.
B. Farnand	B.A.Sc., Ph.D. (Ottawa)	Res. Sci.
G. Jean	D.E.C., B.Sc., Ph.D. (Western Ontario)	Res. Sci.
S.M. Ahmed	B.Sc., M.Sc. (India)	Chemist
G.T. Smiley	Dipl. Elect. (Ryerson)	Technologist

Catalytic Hydroprocessing

J.F. Kriz	Dipl.Eng. (Prague), Ph.D. (Dalhousie), P.Eng.	Res. Sci.
M.F. Wilson	B.Sc., Ph.D. (St. Andrews)	Res. Sci.
M.V.C. Sekhar	B.Sc. (Madras), M.Sc. (ITT-Madras), Ph.D. (Calgary)	Res. Sci.
C.W. Fairbridge	B.Sc., M.Sc. (Lakehead), Ph.D. (St. Andrews)	Res. Sci.
J. Monnier	B.Sc. (Laval), Ph.D. (McMaster)	Res. Sci.
E.C. McColgan		Technologist
M.R. Fulton	Dipl. Chem. Tech. (Algonquin)	Technologist
G. Pachulski	B.A. (Carleton)	Technologist
M. Stolovitsky	Dipl. Biochem. Tech. (Algonquin)	Technologist

Catalysis Research

J.R. Brown	B.Sc., Ph.D. (Western Ontario)	Res. Sci.
J.Z. Galuszka	B.Sc., M.Sc., Ph.D. (Jagiellonian, Cracow, Poland)	Res. Sci.
S.H. Ng	B.Chem. Eng. (Taiwan), Ph.D. (New Brunswick), Eng., Chem.	Res. Sci.
V.M. Allenger	B.A.Eng. (McGill), M.Sc. Chem.Eng. (Ottawa)	Res. Sci.
R.W. Taylor		Technologist
L.E. Galbraith	B.A. (Carleton)	Technologist

STAFF CHANGES

Promotions and Transfers

Boulton, J., from Administration, ERL to Petroleum Incentives Program

Descarie, B., from Administration, ERL to Department of Veterans Affairs, Charlottetown, P.E.I.

Forieri, L., from CR to GS within ERL.

Hill, D., from Administration, ERL to Research Program Office.

Millar, D., Seconded to Finance Section, CANMET.

Retirements

Pleet, M., Technologist, Process Development Operations.

New Employees

Grebenc, M., Clerk, Finance

Hogan, J., (Term) Clerk, Finance

Mallard, P., (Term) Technologist, Analysis & Standardization

New Employees (cont'd)

Boudreau, J., (Term) Clerk, Administration

Lauzon, W., (Term) Clerk, Administration

McCallum, G., (Term) Clerk, Administration

Newhook, K., (Term) Coke Oven Operator, Coal Treatment & Coke Processing Section, CCRL

Preto, F., Research Scientist, Energy Conservation Technology

Roy, M., (Term) Switchboard Operator

Skaff, M., Catalytic Hydroprocessing, HPRL

Vincent, B., (Term) Clerk, Administration - Finance

Weatherall, D.H., (Term) Administration (Driver)

Whelan, V.A., Chemist, Analytical Section

APPENDIX B

REPORTS, PUBLICATIONS, PRESENTATIONS AND PATENTS

CANMET REPORTS

CANMET Report 84-05E	Review of the coprocessing of coals and heavy oils of petroleum origin	J. Monnier

DIVISION REPORTS

ERP = Energy Research Program
ERL = Energy Research Laboratories

JOURNAL SUBMISSIONS (J)

ERP/ERL 84-07(J)	Separation of nitrogenous type compounds from synthetic crudes	G. Jean M. Poirier H. Sawatzky
ERP/ERL 84-17(J)	An evaluation of the use of porous membranes for the dewatering of wellhead/bitumen/water/mineral emulsions	B. Farnand H. Sawatzky M. Poirier
ERP/ERL 84-23(J)	Comparison of CaO, ZnO and Fe_2O_3 as H_2S adsorbents	Motoo Yumura Edward Furimsky
ERP/ERL 84-25(J)	Fluidized bed combustion of a medium-volatile bituminous coal from British Columbia	E.J. Anthony D.L. Desai F.D. Friedrich
ERP/ERL 84-30(J)	H_2S adsorption and decomposition in the presence of manganese nodules	Motoo Yumura Edward Furimsky
ERP/ERL 84-32(J)	Fixed bed and fluidized bed gasification of cokes derived from Athabasca bitumen	E. Furimsky
ERP/ERL 84-35(J)	Hydrogenation of aromatic compounds in synthetic crude distillates catalyzed by sulphided $Ni\text{-}W/\gamma\text{-}Al_2O_3$	M.F. Wilson Jan P. Fisher J.F. Kriz
ERP/ERL 84-36(J)	The separation of nitrogenous compounds from fuels using zeolites	G. Jean S.M. Ahmed H. Sawatzky
ERP/ERL 84-47(J)	Preliminary selection and use of reverse osmosis membranes for the fractionation of naphtha	B.A. Farnand H. Sawatzky

ERP/ERL 84-49(J)	Anomalities of some Western Canadian coals in relation to predictability of coke strength	B.N. Nandi
ERP/ERL 84-51(J)	Catalytic effect of mineral matter of high ash Onakawana lignite on steam gasification	E. Furimsky
ERP/ERL 84-57(J)	Effects of catalytic hydroprocessing in middle distillates from Athabasca syncrudes	M.F. Wilson I.P. Fisher J.F. Kriz
ERP/ERL 84-61(J)	Ultrafiltration development for high quality water from oilfield emulsions	Brian Farnand Henry Sawatzky
ERP/ERL 84-63(J)	Kinetic studies of coke formation in hydrocarbon fractions of heavy crude	D.K. Banerjee K.J. Laidler B.N. Nandi D.J. Patmore
ERP/ERL 84-66(J)	Response to comments on "Upgrading of middle distillate fractions of a syncrude from Athabasca oilsands	M.F. Wilson J.F. Kriz
ERP/ERL 84-71(J)	HPLC separation and GC characterization of polynuclear aromatic fractions of bitumen, heavy oils and their synthetic crude products	S. Coulombe H. Sawatzky
ERP/ERL 85-29(J)	Solid sorbents for removal of hydrogen sulphide from hot gas	E. Furimsky M. Yumura

ORAL PRESENTATIONS (OP)

ERP/ERL 83-58(OP)	Fluidized bed combustion of petroleum coke	F.D. Friedrich G.K. Lee D.L. Desai R. Kuivalainen
ERP/ERL 84-64(OP)	Computer aided derating assessment of oil-designed wall fired utility boilers using coal-water slurry fuel	S.R. Griffin S. Whaley
ERP/ERL 84-03(OP)	Analysis of wood combustion and coal liquefaction by Carbon-13 CPMAS NMR (Extended abstract only)	W.H. Dawson A.C.S. Hayden R.W. Braaten P. Rahimi
ERP/ERL 84-08(OP)	Conversion of acetylene to liquid fuel (Extended abstract only)	V.M. Allenger

ERP/ERL 84-11(OP)	Effect of coal quatity on combustion performance of two LCanadian thermal coals	G.K. Lee F.D. Friedrich H. Whaley
ERP/ERL 84-12(OP)	Systéme de coopération	G. Jean M. Poirier H. Sawatzky
ERP/ERL 84-13(OP)	Separation of nitrogenous compounds from synthetic crudes (Extended abstract only)	G. Jean M. Poirier H. Sawatzky
ERP/ERL 84-14(OP)	Separation and characterization of polynuclear aromatic compounds in bitumen/heavy oil residues and their hydro-cracked products (Extended abstract only)	S. Coulombe H. Sawatzky
ERP/ERL 84-15(OP)	Separation des composés azotes par adsorption (Extended abstract only)	G. Jean M. Poirier H. Sawatzky
ERP/ERL 84-16(OP)	An evaluation of uses for atmospheric fluidized bed combustion solid wastes (Extended abstract only)	E.E. Berry E.J. Anthony
ERP/ERL 84-20(OP)	Effect of calcium-based additives on deposits and emissions from pulverized coal flames	G. Lee R. Prokopuk G.N. Banks H. Whaley
ERP/ERL 84-22(OP)	Third summary report of the status of Canadian CLM projects: IEA coal-liquid mixtures implementing agreement Annex II Base technology	H. Whaley
ERP/ERL 84-27(OP)	CANMET processing: An extension of coal liquefaction and heavy oil hydrocracking technology (Extended abstract only)	J.F. Kelly S. Fouda
ERP/ERL 84-28(OP)	A^{13}C nmr study of coal weathering	J.A. MacPhee B.N. Nandi
ERP/ERL 84-34(OP)	Characterization of coal liquefaction residues by solid state NMR (Abstract only)	W. Dawson P. Rahimi
ERP/ERL 84-37(OP)	Highlights of applied combustion research activities in the Western world	G.K. Lee
ERP/ERL 84-38(OP)	Kinetic studies of coke formation in hydrocarbon fractions of bitumen (Abstract only)	D.K. Banerjee K.J. Laidler D.J. Patmore B.N. Nandi

ERP/ERL 84-39(OP)	Combustion efficiency of washery rejects of North American coals (Abstract only)	B.N. Nandi J.A. MacPhee L.A. Ciavaglia
ERP/ERL 84-41(OP)	Use of low-grade coals as blending coal for blast furnace coke (Abstract only)	B.N. Nandi J.A. MacPhee C. Chornet O. Erbatur
ERP/ERL 84-42(OP)	Assessing coal for combustion	B.N. Nandi J.A. MacPhee L.A. Ciavaglia
ERP/ERL 84-43(OP)	Effect of heat treatment on the properties of asphaltenes from bitumens (Abstract only)	B.N. Nandi J.A. MacPhee L.A. Ciavaglia
ERP/ERL 84-48(OP)	An investigation of coal using secondary ion mass spectrometry (SIMS) (Abstract only)	J.A. MacPhee R.R. Martin M.S. McIntyre
ERP/ERL 84-65(OP)	The CANMET hydrocracking process - application to the Montreal refinery	J.M. Denis T. de Bruijn A. Silva
ERP/ERL 84-67(OP)	Fourth summary report on the status of Canadian CLM projects: IEA coal-liquid mixtures implementing agreement - Annex II Base technology	H. Whaley
ERP/ERL 84-70(OP)	Process control for heavy oil upgrading (Abstract only)	F.T.T. Ng D.J. Patmore
ERP/ERL 85-05(OP)	Destabilization of emulsions from Western Canadian bitumen recovery operations and characterization of isolated surfactants (Abstract only)	S. Coulombe B. Farnand H. Sawatzky
ERP/ERL 85-06(OP)	Sorption of synthetic crude nitrogenous compounds (Abstract only)	G. Jean E. Bonvie H. Sawatzky
ERP/ERL 85-07(OP)	Characterization of polyaromatic fractions from crude oil vacuum bottoms and their hydrocracked products (CANMET process) (Abstract only)	S. Coulombe H. Sawatzky
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ERP/ERL 85-16(OP)	Probing the structures of solid asphaltenes by carbon NMR - Uses and abuses of relaxation time phenomena (Abstract only)	D. Axelson W.H. Dawson

ORAL PRESENTATIONS AND JOURNAL SUBMISSIONS (OPJ)

ERP/ERL 84-02(OPJ)	Surface chemical characterization of a sulphided CO, MO-γalumina HDS catalyst by XPS/AES/SAM	J.R. Brown
ERP/ERL 84-09(OPJ)	Effect of adding process residues on the physical properties and composition of asphalt cements	M.A. Poirier H. Sawatzky
ERP/ERL 84-10(OPJ)	Removal of synthetic crude nitrogenous compounds using waste materials	G. Jean M. Poirier H. Sawatzky
ERP/ERL 84-18(OPJ)	Utility boiler demonstration of coal-water mixture combustion of Chatham, New Brunswick	H. Whaley R.M. Rankin P.G. Landry I.D. Covill
ERP/ERL 84-24(OPJ)	The control of NO_x and SO_x emissions from conventional pulverized coal flames: the Canadian program	G.K. Lee
ERP/ERL 84-26(OPJ)	Combustion trials of coal-water mixture fuel in two small utility boilers in Eastern Canada	H. Whaley D.M. Rankin P.J. Read
ERP/ERL 84-29(OPJ)	Effects of catalyst pore structure on the conversion of asphaltenes in Athabasca bitumen	M.V.C. Sekhar
ERP/ERL 84-49(OPJ)	The utilization of crude bitumen as a boiler fuel	G.K. Lee H. Whaley R. Prokopuk G.N. Banks
ERP/ERL 84-44(OPJ)	Coprocessing of Canadian lignites and bitumen	G.K. Lee H. Whaley R. Prokapuk G.N. Banks
ERP/ERL 84-44(OPJ)	Coprocessing of Canadian lignites and bitumen	S.A. Fouda M. Ikura J.F. Kelly
ERP/ERL 84-45(OPJ)	Microscopic examination of coke in relation to chemical and physical properties of coal (Abstract only)	B.N. Nandi J.A. MacPhee L.A. Ciavaglia
ERP/ERL 84-46(OPJ)	Aspects of coal weathering as studied by spectroscopic and chemical techniques (Abstract only)	J.A. MacPhee B.N. Nandi J.A. Ripmeester C. Ratcliffe

ERP/ERL 84-50(OPJ)	Cetane improvement of middle distillates from oil sands by catalytic hydroprocessing (Abstract only)	M.F. Wilson J.F. Kriz I.P. Fisher
ERP/ERL 84-52(OPJ)	CANMET coprocessing: a status report	J.F. Kelly S.A. Fouda P.M. Rahimi M. Ikura
ERP/ERL 84-53(OPJ)	Chemical and physical characteristics of test fuels in CANMET's residential oil heating program	R.J. Lafleur S. Win Lee
ERP/ERL 84-56(OPJ)	Catalyst performance in hydroprocessing H-Coal middle distillate	C. Fairbridge J. Kriz
ERP/ERL 84-60(OPJ)	Characterization of hydrocracking catalysts by chemisorption and surface analysis (Abstract only)	C. Fairbridge M.V.C. Sekhar J.R. Brown
ERP/ERL 84-60(OPJ)	Hysteresis caused by dimensional changes of porous solids during mercury porosimetry (Abstract only)	Marten Ternan Luigi P. Mysak
ERP/ERL 84-64(OPJ)	The CANMET coal hydropyrolysis project	P.L. Sears A.J. Last C.F. Peczeli
ERP/ERL 84-68(OPJ)	Experimental facilities and procedures for determining the effects of fuel oil quality on burner performance	S.W. Lee
ERP/ERL 84-72(OPJ)	Surface chemistry of a Co, Mo-alumina catalyst: effects of calcination	J.R. Brown
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ERP/ERL 85-03(OPJ)	Catalytic hydroprocessing of Canadian syncrudes: R&D interests at CANMET	J.F. Kriz C. Fairbridge M.F. Wilson

ERP/ERL 85-04(OPJ)	Etude du mécanisme de l'oxydation d'un charbon bitumineux	J.A. MacPhee B.N. Nandi
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ERP/ERL 85-09(OPJ)	Influence of reducing gas in the coprocessing of coal and bitumen	S. Coulombe P. Rahimi S. Fouda M. Ikura H. Sawatzky
ERP/ERL 85-10(OPJ)	Selective removal of nitrogenous compounds using zeolites	G. Jean E. Bonvie H. Sawatzky
ERP/ERL 85-13(OPJ)	Catalytic hydroprocessing of mixtures of heavy oil and coal	J. Monnier J. Kriz
ERP/ERL 85-14(OPJ)	Hydrocarbon type separation of middle distillates and asphalt cement fractions	S. Coulombe M.A. Poirier
ERP/ERL 85-15(OPJ)	Effect of blend composition, coal size and coking rate on gas pressure and coke properties in Algoma's No. 6 battery	Mohammed A. Khan J.F. Gransden J.T. Price
ERP/ERL 85-17(OPJ)	The use of H_2S as a promoter in coprocessing low-rank Canadian coals and bitumen	P.M. Rahimi J.F. Kelly
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ERP/ERL 85-25(OPJ)	Mesophase formation in hydrocarbon fractions of bitumen	D.D.S. Liu D.J. Patmore
ERP/ERL 85-26(OPJ)	Large pore catalysts for viscosity reduction of heavy feeds (Abstract only)	M.V.C. Sekhar
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ERP/ERL 85-28(OPJ)	The role of coke microscopy in coal carbonization	J.F. Gransden J.T. Price N.J. Ramey
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TECHNICAL REPORTS (TR)

ERP/ERL 83-72(TR)	Microscopy of coke from three Canadian coals with pitch additives	N.J. Ramey J.F. Gransden J.T. Price
ERP/ERL 84-06(TR)	Evaluation of laboratory fluid catalytic cracking systems	C.B. Prakash
ERP/ERL 84-19(TR)	A metal analysis survey of 43 Canadian commercial coals	M. Farrell
ERP/ERL 84-21(TR)	Production of boiler feed quality water from wellhead bitumen/water/mineral emulsion by using porous membranes	C. Nadar B.A. Farnand H. Sawatzky
ERP/ERL 84-31(TR)	Development of a bench-scale fluidized bed combustor for coal reactivity studies	Ivan T. Lau
ERP/ERL 84-54(TR)	Reverse osmosis fractionation of petroleum and synthetic crude distillates	B.A. Farnand H. Sawatzky
ERP/ERL 84-58(TR)	The use of basic nitrogenous compounds in the liquefaction of high-volatile bituminous coal	P.L. Sears J.A. McVeigh

ERP/ERL 84-73(TR)	Natural gas to liquid fuels via acetylene	V.M. Allenger
ERP/ERL 85-12(TR)	Hydrocarbon Processing Research Laboratory - Progress Report 1984	Staff HPRL

RESEARCH REPORTS (R)

ERP/ERL 84-05(R)	Review of coprocessing coals and heavy oils of petroleum origin	J. Monnier
ERP/ERL 84-62(R)	Comparison of combustion and heat transfer characteristics of Cape Breton Development Corporation coal water fuel with pulverized coal and No. 6 fuel oil	K. Thambimuthu J. Wong B. Cox B. Post H. Whaley
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INTERNAL REPORTS (INT)

ERP/ERL 84-01(INT)	Thermodynamic evaluation of metal oxides as potential H_2S adsorbents	M. Yumura E. Furimsky
ERP/ERL 84-02(INT)	Preliminary report on the fluidized-bed combustion trials of pelletized paper product in the fluidized-bed pilot-scale combustor at the Combustion and Carbonization Research Laboratory	E.J. Anthony D.L. Desai V. Razbin
ERP/ERL 84-03(INT)	Membrane filtration for solid/liquid separation of coal and heavy/oil bitumen coprocessing product	B.A. Farnand P. Rahimi S. Fouda H. Sawatzky
ERP/ERL 85-01(INT)	Determination of aromatic hydrocarbons in middle distillates from synthetic crudes using ultraviolet spectrophotometry	V. Whelan

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Kelly, J.F. and Fouda, S.A. "CANMET coprocessing: An extension of coal liquefaction and heavy oil hydrocracking technologies"; presented Dept. of Energy's Direct Coal Liquefaction Contractors' Review Meeting, Albuquerque, N.M., Oct. 17-18, 1984.

Khulbe, K., Back, M.H. and Galuszka, J. "The role of the morphology of the carbon deposit on films on iron in the Fischer-Tropsch reaction"; Catalysis Discussion Group Meeting, May 14, 1984.

Kriz, J.F. "Hydrocracking heavy hydrocarbon feedstocks: Aspects of catalysis related to feedstock coking tendency"; 9th Canadian Catalysis Symposium, Quebec City, Sept. 1984.

Lee, S.W. "Effect of oil quality on burner performance"; presented Ontario Petroleum Association Technical Committee; Toronto, Jan. 1984.

Lee, S.W. "Experimental apparatus to measure domestic oil burner performance"; presented ERL, Oct. 1984.

MacPhee, J.A. and Nandi, B.N. "Applications of new spectroscopic techniques to coal science"; presented NATO Advanced Study Institute, Antigonish, Nova Scotia, Aug. 5-18, 1984.

MacPhee, J.A. and Nandi, B.N. "A ^{13}C NMR Study of Coal Weathering"; presented Canadian Spectroscopy Society Meeting, Gray Rocks, Quebec, Oct. 1-13, 1984.

Nandi, B.N., MacPhee, J.A. "Combustion efficiency of washery rejects by North American coals"; presented 7th International Coal and Lignite Conference, Houston, Texas, Nov. 13-15, 1984.

Nandi, B.N. "The role of coal petrography in combustion"; American Organic Petrology Society, Washington, D.C., Aug. 1984.

Ng, F.T.T. "Asphaltene conversion with the CANMET hydrocracking process"; presented Oak Ridge National Laboratory, Nov. 1984 and at W.R. Grace and Co., Nov. 1984.

Poirier, M.A. "Caractérisation des hydrocarbures aromatiques polycycliques dans des distillats de points d'ébullition 350°C par GC/MS"; presented Institut Francais du Pétrole, Rueil-Malmaison, France, June 21, 1984.

Poirier, M.A. "Séparation et identification des composés sulfurés dans des coupes de distillation d'huile lourde de Lloydminster par couplage chromatographie en phase gazeuse-spectrométrie de masse"; presented Congrés International des Huiles Lourdes, Lyon, France, June 25-27, 1984.

Poirier, M.A. "Recherche et activités au Laboratoires de recherche sur l'énergie"; presented Institut Francais du Pétrole, Rueil-Malmaison, France, June 21, 1984.

Poirier, M.A. "The utilization of CANMET hydrocracked pitches for the production of road asphalts"; presented ERL, March 1984.

Poirier, M.A. "Les Laboratoires de recherche sur l'énerqie (CANMET)"; presented TOTAL-Compaqnie Francaise de Raffinage, June 1984.

Poirier, M.A. "La caractérisation des hydrocarbures polyaromatiques dans une coupe pétroliere par GC/MS"; presented TOTAL-Compagnie Française de Raffinage, June 1984.

Poirier, M.A. "TOTAL-Compagnie Francaise de Raffinage, Research and activities"; presented ERL, Nov. 1984.

Poirier, M.A. "The blending of CANMET hydrocracked pitches for the production of road asphalt"; presented Petro-Canada, Toronto, Feb. 28, 1984.

Razbin, V.V., Anthony, E.J., Desai, D.L. and Friedrich, F.D. "The fluidized bed combustion of a high sulphur Maritime coal"; Joint Power Generating Conference, Toronto, Oct. 1984.

Sekhar, M.V.C. "Effects of pore structure on the conversion of asphaltenes in Athabasca bitumen"; CAICLE Spring Nat. Conf., Houston, Texas, March 1985.

Ternan, M. "Valorization des huiles lourdes"; University of Sherbrooke; March 1984.

Ternan, M. "Bitumen and catalysis"; University of Alberta, June 1984.

Ternan, M. "Hydrocarbon upgrading technology for use in separation and conversion processes"; Association of Consulting Engineers of Canada, Jan. 1984.

Wilson, M.F. "Selected aspects of catalytic refining of middle distillates from Athabasca syncrudes"; American Chemical Society, Division of Petroleum Chemistry, St. Louis, MO, Apr. 1984 and at ERL, March 1984.

Wong, B.Y., Simpson, P. and Fung, D.P.C. "Thermal upgrading of low rank coals with heavy residua"; presented 34th Canadian Chemical Engineering Conference, Quebec City, Sept. 30, 1984.

PATENTS

ISSUED

Belinko, K., Patmore, D.J., Packwood, R.H. and Ranganathan, R. "Simultaneous demetallization and hydrocracking of heavy hydrocarbon oils"; UK Patent 2,093,058; June 1984.

APPLIED FOR

Cooke, N.E., Khandadia, P. and Furimsky, E. "A novel method for removing oxygen from coal", Canadian Patent Office application 460,989, (filed Aug. 14, 1984).

Farnand, B.A., Poirier, M.A., Sawatzky, H. "Process for selectively removing stabilizing components from bitumen/water emulsions", CANMET Case No. 40, Kirby, Shapiro, Eades & Cohen File 22507.

Farnand, B.A. and Sawatzky, H. "Reverse osmosis fractionation of petroleum and synthetic crude distillates", Kirby, Shapiro, Eades & Cohen File 24046.

Furimsky, E. and Yumura, M. "New adsorbent for removing hydrogen sulphide from hot gas prepared from manganese nodules", Kirby, Shapiro, Eades & Cohen File 2204 (Oct. 1, 1984).

Poirier, M.A. "Road asphalt compositions containing hydrocracked pitch", Canada Patent Application File No. 21665, September 10, 1984. Can. Pat. 462,790.

Wilson, M.F., Kriz, J.F. "Preparation of hydrocarbon fuel by hydrogenation of a synthetic crude middle distillate"; Can. Patent Application 462,789; Sept. 1984.

APPENDIX C

REPRESENTATION ON TECHNICAL COMMITTEES

INTERNATIONAL

BRITISH FLAME RESEARCH COMMITTEE (member)	G.K. Lee
CANADA/JAPAN COAL LIQUEFACTION PROGRAM	
Working Group (member)	M. Ikura
INTERNATIONAL CONGRESS ON CATALYSIS	
Advertising and Publications Committee (Chairman)	M. Ternan
(Member)	J. Monnier
INTERNATIONAL COMMITTEE ON COAL PETROGRAPHY	
Petrography (working member)	B.N. Nandi
Petrography of Organic Sediments (member)	B.N. Nandi
Subcommittee on Industrial Application of Coal Petrography (member)	B.N. Nandi
INTERNATIONAL ENERGY AGENCY	
Coal-liquid Mixture Implementing Agreement	H. Whaley
Atmospheric Fluidized Bed Combustion Agreement	F.D. Friedrich
Low NO_x Coal Combustion of Pulverized Coal Agreement	G.K. Lee
Organizing Committee - International Conference on Coal Science	J.T. Price
INTERNATIONAL FLAME RESEARCH FOUNDATION	
Aerodynamics Panel (member)	H. Whaley
Flame Chemistry Panel (member)	E.J. Anthony
Joint Committee (member)	G.K. Lee
Pulverized Coal Panel (member)	H. Whaley
Oil and Gas Panel (member)	A.C.S. Hayden
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)	
ISO/TC-27 Solid Mineral Fuels Canadian Advisory Committee (chairman)	L. Janke
ISO/TC-27/SC-2 Brown Coals & Lignites (secretary)	L. Janke
(member at large)	R. Prokopuk
ISO/TC-27/SC-2/WG-15 Coal Abrasion (member)	R. Prokopuk
ISO/TC-27/SC-3 Coke (member)	R. Prokopuk
ISO/TC-27/WG-12 Plasticity (member)	J.F. Gransden
ISO/TC-102/SC-3 Physical Testing of Iron Ores (chairman)	T.A. Lloyd
ISO/TC-109 Domestic Oil Burners (member)	J.T. Price
ISO/TC-146/SC-1 Air Quality - Stationary Source Emissions (member)	A.C.S. Hayden
	H. Whaley
ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT	
Long Range Transport of Air Pollution (member)	H. Whaley
Waste Heat Utilization (member)	F.D. Friedrich
US/CANADA MEMORANDUM OF UNDERSTANDING FOR COOPERATION ON RESEARCH AND DEVELOPMENT IN TAR SANDS (OIL SANDS) AND HEAVY OIL	
Executive Committee (Canadian Chairman)	B.I. Parsons

US/CANADA INTERAGENCY WOOD COMBUSTION
Research Group (member) .... A.C.S. Hayden

UNITED NATIONS INFOTERRA INTERNATIONAL DIRECTORY OF SOURCES
(Environmental Expert member) .... R. Prokopuk

WOOD HEATING ALLIANCE
Engineering Committee (member) .... A.C.S. Hayden
Emissions Subcommittee (member) .... R.W. Braaten

UNITED STATES OF AMERICA

AIR POLLUTION CONTROL ASSOCIATION
Residential Fuel Combustion (chairman) .... A.C.S. Hayden
Air Pollution (member at large) .... R. Prokopuk
Residential Fuel Combustion Committee TS 2.3 (chairman) .. A.C.S. Hayden

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
Air Pollution Control Division General Committee
(member) .... H. Whaley
Fuels Division Research Committee (member) .... G.K. Lee
Research Committee on Corrosion and Deposits from
Combustion Gases (member) .... G.K. Lee
Task force on Energy Conversion Research (member) .... G.K. Lee
Honors and Awards Committee, Papers Review,
Fuels Division (member) .... H. Whaley
APCD Papers Review Committee (member) .... H. Whaley
American Power Conference Organization Committee (member). H. Whaley

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
Committee D-2 Petroleum Products and Lubricants (member) . R.J. Lafleur
Committee D-5 Membership Secretary .... L. Janke
Committee D-5 Executive (member) .... L. Janke
Committee D-5 (member) .... M.D. Farrell
Committee D-34 Waste Disposal (member) .... E.J. Anthony
Committee D-38 Utilization of Waste Materials (member) ... E.J. Anthony
Committee D-22 Environmental Monitoring and Assessment
(member) .... R. Prokopuk
Subcommittee D-5-07 Physical Properties of Coal (member) . T.A. Lloyd
Subcommittee D-5-22 Physical Testing of Coke (member) .... T.A. Lloyd
Subcommittee D-5-28 Petrographic Analysis of Coal
(members)... B.N. Nandi
.... J.C. Jorgensen
Wood Stove Performance Measurement (member) .... R.W. Braaten

NATIONAL ENGINEERING FOUNDATION
Fuels for Tomorrow Conference Organizing Committee
(member).. G.K. Lee
Fouling and Slagging from Fuel Impurities Conference
Organizing Committee (member) .... G.K. Lee

UNITED STATES OF AMERICA FOREST PRODUCTS RESEARCH
Society Editorial Review Board (member) .... D.P.C. Fung

UNITED STATES DEPARTMENT OF ENERGY
CLM Standards and Practices Committee (member) .... H. Whaley
CLM Combustion Subcommittee (chairman) .... H. Whaley

CANADA - FEDERAL

CANADIAN GENERAL STANDARDS BOARD
Committee 3-GP, Petroleum Test Methods Subcommittee
(member)... M.F. Wilson
Middle Distillate Fuels Subcommittee (member) .... A.C.S. Hayden
Committee on Distillate Fuels (chairman) .... A.C.S. Hayden
Subcommittee on Heating Fuels (chairman) .... A.C.S. Hayden
Gasoline and Alternative Automotive Fuels (member) .... A.C.S. Hayden
Committee on Stationary Combustion (chairman) .... A.C.S. Hayden
Committee on Petroleum (member) .... R.J. Lafleur
Subcommittee on Test Methods (member) .... R.J. Lafleur
Committee on Identification of Medical Gas Cylinders,
Pipelines and Flush-type Valves .... L.P. Mysak

ENERGY, MINES AND RESOURCES CANADA
Canada/Saskatchewan Heavy Oil/Fossil Fuels Agreement
Management Committee (member) .... B.I. Parsons
Technical Advisory Committee (member) .... M.F. Wilson
Canada/New Brunswick Coal-Oil Shale Combustion Agreement
Management Board (member) .... G.K. Lee
CANMET Hydrocracking
Liaison Committee (chairman) .... J.M. Denis
Patents and Publications Committee (member) .... J.M. Denis
Patent Coordination (representative) .... D.J. Patmore
Research and Development Committee (members) .... J.M. Denis
.... D.J. Patmore
Reactor Modelling and Simulation Committee (members) ... T.J. de Bruijn
.... D.D.S. Liu

HYDROCARBON RESEARCH CENTRE - UNIVERSITY OF ALBERTA
Board of Directors (member) .... B.I. Parsons

INTERDEPARTMENTAL
Automobile Emission Standards (member) .... A.C.S. Hayden
Building Research and Development (member) .... A.C.S. Hayden
Evaluation of Fuels and Lubricants (member) .... M.F. Wilson
Lead in Gasoline (member) .... A.C.S. Hayden
Fuel Committee (member) .... F.D. Friedrich
Management Committee for CANMET Hydrocracking (chairman) . J.M. Denis
Retrofit Devices and Additives (member) .... A.C.S. Hayden
Task Force on Stack Height Estimation (member) .... H. Whaley
Future Liquid Fuel Use (member) .... A.C.S. Hayden

NATIONAL COAL CONVERSION COMMITTEE
Executive Committee (member) .... M. Ikura

NATIONAL RESEARCH COUNCIL ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR ENVIRONMENTAL QUALITY
Committee on Emissions from Residential Combustion Appliances (chairman) .... A.C.S. Hayden

TRANSPORT CANADA
Steering Committee on Coal Slurry Pipeline Transport (member) .... M. Ikura

CANADA - MISCELLANEOUS

AIR POLLUTION CONTROL ASSOCIATION
(Quebec Section) (past chairman) .... R.J. Lafleur

AOSTRA/INDUSTRY/EMR
Heavy Oil Pipelinability Study (member) .... A.E. George
Oil Sands Demonstration Centre Management Committee (member) .... D.K. Faurschou
Upgrader Selection Study (member) .... J.M. Denis
Upgrader Residue Utilization Study (member) .... F.D. Friedrich

ATLANTIC COAL LIQUID MIXTURE WORKING GROUP (member) .... H. Whaley

ATLANTIC GROUP FOR RESEARCH AND INDUSTRIAL MATERIALS
(EMR representative) .... P.L. Sears

CANADIAN ELECTRICAL ASSOCIATION
Advisory Panel of Flue Gas Desulphurization .... G.K. Lee

CANADIAN CARBONIZATION RESEARCH ASSOCIATION
Board of Directors (secretary) .... J.T. Price
Technical Committee (secretary)........................... J.G. Jorgensen
(member) .... J.F. Gransden

CANADIAN COAL PETROGRAPHERS GROUP (secretary) .... B.N. Nandi
(member) .... J.G. Jorgensen

CANADIAN GAS ASSOCIATION
Standards Committee (member) .... G.K. Lee

CANADIAN GAS RESEARCH INSTITUTE (director) .... G.K. Lee

CANADIAN INSTITUTE OF ENERGY (director) .... F.D. Friedrich
Ottawa Branch (treasurer) .... E.J. Anthony

CANADIAN SOCIETY FOR CHEMICAL ENGINEERING
Ottawa-Hull Section Executive (chairman) .... S.A. Fouda
(vice-chairman) .... M.I. Ikura
(secretary) .... J.D. Chase
(members) .... V. Allenger
.... J. Monnier
.... B. Farnand

CANADIAN SOCIETY FOR CHEMICAL ENGINEERING (cont'd)
Continuing Conference Program Subcommittee
Local Section (representative) .... J.F. Kriz

CANADIAN STANDARDS ASSOCIATION
Subcommittee on Chimney Dampers (member) .... A.C.S. Hayden
Subcommittee on Automotive Flue Pipe .... A.C.S. Hayden
Air Pollution Control (executive) .... H. Whaley
Incinerator Performance (member) .... F.D. Friedrich
Fire Safety .... A.C.S. Hayden
Positive Chimney Dampers (member) .... A.C.S. Hayden
Oil Heating Systems (member) .... A.C.S. Hayden
Oil Burning Equipment (member) .... A.C.S. Hayden
Retrofitting of Oil Burners (member) .... R.W. Braaten
Sampling Emissions and Measurements (chairman) .... H. Whaley
(member) .... R. Prokopuk
Solid Fuel Installation (member) .... R.W. Braaten
Energy Evaluation of Houses (member) .... A.C.S. Hayden
Subcommittee on Analytical Procedures (member) .... A.C.S. Hayden
Subcommittee on Experimental Procedures (member) .... R.W. Braaten
Subcommittee on Analytical Techniques for Housing
(member) .... A.C.S. Hayden
Sampling Emissions and Measurements (chairman) .... H. Whaley
(member) .... R. Prokopuk
Installation Code for Solid Fuel Burning Appliances
(member) .... R.W. Braaten
Task Force on Performance Standard for Wood Stoves
(member) .... R.W. Braaten
Wood-fired appliances (member) .... A.C.S. Hayden
Solid Fuel Fired Space Heaters (member) .... A.C.S. Hayden
Energy Evaluation of Houses (member) .... A.C.S. Hayden
Seasonal Performance of Gas-Fired Appliances (member) .... A.C.S. Hayden
Masonary Chimneys and Fireplaces (member) .... A.C.S. Hayden
R&D Requirements for Venting Systems (member) .... A.C.S. Hayden

CHEMICAL INSTITUTE OF CANADA
Catalysis Division (secretary-treasurer) .... J.F. Kriz
Ottawa-Hull Section Executive Committee (ex-officio
member) .... J. Monnier

HOUSING AND URBAN DEVELOPMENT ASSOCIATION OF CANADA (HUDAC)
Future Space Conditioning Requirements (chairman) .... A.C.S. Hayden
Controlled Ventilation and Heat Recovery (member) .... A.C.S. Hayden
Technical Research Committee (member) .... A.C.S. Hayden

UNDERWRITERS LABORATORIES OF CANADA/CANADIAN
STANDARDS ASSOCIATION
Joint Committee on Wood Burning Appliances (member) ...... A.C.S. Hayden

ATLANTIC COAL-LIQUID MIXTURE WORKING GROUP (member) .... H. Whaley

APPENDIX D

CONTRACTS, RESEARCH AGREEMENTS AND COST RECOVERY WORK

CONTRACTS AND RESEARCH AGREEMENTS

Contract Title	Contractor	Scientific Authority	Status
Development and evaluation of catalysts for hydrogenation of condensed PNA compounds	Guelph Chemical Laboratories	M. Sekhar	Completed
Treatment of pitch with methanol	Sandwell Beak Research Group	M. Poirier	Under negotiation
Literature review on pitch utilization and technical proposal for a catalytic pitch conversion system	Hatch Associates	S. Ng	Under negotiation
Evaluation of metal-tolerant fluid catalytic cracking catalysts by molecular probes	Gulf Canada	S. Ng	Under negotiation
Upgrading of residual heavy oil by vacuum pyrolysis	Sherbrooke Univ.	J. Monnier	In progress
Analytical methods development and characterization requirements for the Canada/US cooperation projects on resource characterization	Alberta Research Council	R. Lafleur	In progress
Selective identification of olefins and paraffins in synthetic crude middle distillate	RFP	S. Coulombe	Under negotiation
Molecular weight determination of asphalt samples by gel permeation chromatography	Ontario Research Foundation	M. Poirier	Completed
Diesel and middle distillate quality and yield improvement	Gulf Canada	H. Sawatzky	In progress
Compositional study of N&O compounds in products of heavy oil primary and secondary upgrading	Gulf Canada	S. Coulombe	In progress
Technical and economic assessment of the application of membrane technology for treating oil/water/mineral emulsions	Zenon Environmental Inc.	B. Farnand	In progress
The evaluation of adsorbents for treating stable oil/water/mineral emulsions producing in-situ bitumen/heavy oil recovery	Zenon Environmental Inc.	M. Poirier	In progress

Contract Title	Contractor	Scientific Authority	Status
Reverse osmosis separation of model compounds in heptane and toluene solutions	RFP	B. Farnand	Under negotiation
Investigation of extraction of catalyst deactivating components from synthetic crudes with CO_2 & N_2O	RFP	H. Sawatzky	Under negotiation
Separation of nitrogeneous materials from naphtha	RFP	G. Jean	Under negotiation
Novel concepts for segregation of problematic components	RFP	H. Sawatzky	Under negotiation
Exploration investigation on low pressure rotating dynamic membrane process for treating bitumen/water/mineral emulsions	SNC	B. Farnand	Under negotiation
Adsorption of nitrogen compounds	Laval Univ.	G. Jean	Under negotiation
The impact of problematic components on synthetic crude processing	Gulf Canada	H. Sawatzky	In progress
Separation of saturated and aromatic components from synthetic crudes	Gulf Canada	B. Farnand	In progress
Compositional analysis of hydrotreated middle distillates from synthetic crudes by mass spectroscopy	Gulf Canada	M. Wilson	In progress
Determination of aromatics in oil sand distillates	Carleton Univ.	M. Wilson	Completed
Hydrogenation of model compounds	SNC	E. Furimsky	In progress
The fabrication of thin film well defined Co, Mo-alumina catalysts and their surface characterization	University of Western Ontario	J.R. Brown	Completed
Hydroprocessing of aromatics using thin film Co, Mo-alumina catalyst surfaces	University of Western Ontario	J.R. Brown	In progress
Characterization and storage stability of untreated and hydrotreated liquids from SB pyrolysis of Canadian coals	University of British Columbia	M. Skubnik	In progress

Contract Title	Contractor	Scientific Authority	Status
Analysis of synthetic crude middle distillate fractions by C-13 NMR	Carleton Univ.	M. Wilson	In progress
Software development for automated R&D reactor system in distillate upgrading	Sharon Professional Services	C. Fairbridge	In progress
Pilot scale conversion of Estevan lignite into hydrocarbon distillate by hydroprocessing using Sandwell Centrax process	Sandwell Beak Research Group	C. Fairbridge	Completed
Preparation of new metal catalysts supported on ZSM5 for the deoxygenation of organic compounds	Laval Univ.	J. Monnier	In progress
Development of rapid GC/MS method using a Finnigan 4500 GC/MS instrument	Zenon Environmental Inc.	R. Lafleur	In progress
Jet and diesel fuel products from hydrocracked fractions of heavy feedstocks	Imperial Oil	F. Ng	Completed
Upgrading of synthetic crude distillates with commercial hydrotreating catalysts	RFP	M. Sekhar	In progress
Role of catalysts in heteroatom removal during hydroprocessing of model compounds	University of Alberta	C. Fairbridge	In progress
Development of improved synthetic crude processes and their impact on distillate and other product qualities	Gulf Canada	M. Wilson	Completed
Study of incorporating heavy oil and synthetic crude residua into FCC feedstock	Gulf Canada	S. Ng	Completed
The impact of N-compounds on the processing of synthetic gas oil	Gulf Canada	J. Monnier	In progress
Hydrogenation and its effect on synthetic crude - FCC	Gulf Canada	S. Ng	In progress

Contract Title	Contractor	Scientific Authority	Status
Development and performance tests of a new catalyst for conversion of alcohols to gasoline	Centre de recherche industrielle du Québec	G. Jean	In progress
Direct production of aromatic hydrocarbons/gasoline from synthesis gas	University of Saskatchewan	S. Ng	Completed
Carbon deposit morphology on metal surfaces during hydrocarbon synthesis	University of Ottawa	J. Galuszka	In progress
Study on direct oxidation of natural gas to methanol	University of Manitoba	D. Fung	In progress
Préparation et caractérisation des zéolithes de la famille pentasil	Laval Univ.	V. Allenger	Completed
Conversion du méthane en essence automobile par réaction en cathode creuse	Chicoutimi University	V. Allenger	In progress
Automation of a high pressure reactor system	Stearns Catalytic	J. Galuszka	Completed
Novel concepts for direct conversion of natural gas to liquid fuels	RFP	H. Sawatzky J. Galuszka	Under negotiation
Direct partial oxidation of methane to methanol over designed heteropoly catalysts	University of Waterloo	J.R. Brown	In progress
Direct production of gasoline range hydrocarbons from syngas in a dual-bed reactor system	University of Saskatchewan	S. Ng	In progress
Project gaso/syn	Concordia Univ.	G. Jean	In progress
Gasoline from natural gas	SNC	D. Fung	Completed
Technical and economic assessment of producing distillate fuels via an electricity based acetylene process	SNC	D. Fung	In progress
Gaz de synthese/essence synthétique première pertie	Centre de recherche industrielle du Québec	G. Jean	In progress

Contract Title	Contractor	Scientific Authority	Status
Gasification of Western Canadian coals in a spouted bed	University of British Columbia	D. Fung	Completed
Gasification of oil sands coke	University of British Columbia	D. Fung	In progress
Rapid pyrolysis of New Brunswick oil shales	University of British Columbia	E. Furimsky	In progress
Effect of temperature and hydrogen pressure on liquid yields from selected oil shales	Res. and Prod. Council	E. Furimsky	In progress
Entrained bed gasification of Suncor and Syncrude coke	Texaco	E. Furimsky	Under negotiation
Evaluation of processing options for the oil shales of Ontario	Watt, Griffis and McOuat	M. Skubnik	Under negotiation
Upgrading of Nova Scotia oil shales	Technical University of Nova Scotia	L. Janke	In progress
Gasification reactivities of ultrasonically treated coal rejects	Carleton University	B. Nandi	In progress
A demonstration of an integrated oil shale system	Res. and Prod. Council	E. Furimsky	In progress
Conversion of coal rejects to liquid fuels via indirect liquefaction	Westar/Esso	E. Furimsky	In progress
Integrated produced water treatment/coke desulphurization process, Phase I	Ontario Research Foundation	D.K. Faurschou	In progress
Simulated in-situ recovery of oil using steam: Phase I Basic low-pressure scaled physical modelling	University of Alberta	D.K. Faurschou	In progress
Numerical simulation of steam injection in bitumen and heavy oil reservoirs	University of Toronto	D.K. Faurschou	In progress
Influence of the reservoir matrix on the mechanism and kinetics of the insite combustion process for heavy oil recovery	Gulf Canada	D. Faurschou	In progress

Contract Title	Contractor	Scientific Authority	Status
The use of surfactant waterproofing as an enhanced recovery process for heavy oil	Gulf Canada	D. Faurschou	In progress
Oil sand demonstration centre, Phase III	AOSTRA (Chevron, NOVA, P-C Shell)	D. Faurschou	In progress
Oil sand demonstration centre, Phase IV	AOSTRA (Chevron, NOVA, P-C, Shell)	D. Faurschou	Under negotiation
X-ray densitometer for CANMET hydrocracking unit and co-processing units	Atomic Energy of Canada	D.D.S. Liu	Completed
Residence time distribution studies for scale-up of the CANMET hydrocracking process	University of Waterloo	T. de Bruijn	In progress
Hydropyrolysis of CANMET pitch	Ontario Research Foundation	P. Sears	Completed
Study on the nature of coke from low rank coal and heavy oil	University of Sherbrooke	J.A. MacPhee	In progress
High temperature EPR studies of the thermolysis of heavy oil and its components	University of Guelph	F. Ng	In progress
Kinetic studies of coke formation in hydrocarbon fractions, Phase II	University of Ottawa	B. Nandi	In progress
Lignite beneficiation as an integral part of direct liquefaction	SNC	R. Mikula (CRL-Edmonton)	In progress
Evaluation of a flash liquefaction pyrolysis process applicable to Canadian coals	University of Waterloo	S. Fouda	In progress
Flash hydropyrolysis project at Ontario Research Foundation	Ontario Research Foundation	P. Sears	Completed
Direct coal liquefaction under ambient conditions	University of Victoria	P. Rahimi	In progress

Contract Title	Contractor	Scientific Authority	Status
Critical evaluation of the Centrax Process for solid-liquid separation of coal liquids	Mitre Corp. U.S.A.	J. Kelly M. Ikura	In progress
Critical evaluation of the hardware development for the Sandwell Centrax Process	McMaster University	J. Kelly M. Ikura	Under negotiation
Characterization of solid residue from coal liquefaction processes 1984/85	University of Regina	W. Dawson	In progress
Flash hydropyrolysis of coal at Ontario Research Foundation	Ontario Research Foundation	P. Sears	In progress
Liquefaction studies of Nova Scotia coals	Nova Scotia Research Foundation Corp.	D. Faurschou	Completed
Continuous liquefaction of Hat Creek coal	B.C. Research	S. Fouda	Completed
Liquefaction of Hat Creek coal	B.C. Research	S. Fouda	In progress
Liquefaction studies on Nova Scotia coals, Phase VI	Nova Scotia Research Foundation Corp.	D. Faurschou	In progress
Evaluation of the integration of the Sandwell Centrax Process into the American two-stage liquefaction process - Phase I, II, III	Sandwell Beak Research Group	J. Kelly	Under negotiation
Investigation of the use of spherical agglomeration for coal pretreatment in CANMET coprocessing	SNC	M. Ikura	On hold
Techo-economic study of CANMET coprocessing technology - 20,000 bbl/day syncrude from Cold Lake bitumen	Partec Lavalin	M. Ikura J. Kelly R. Dunn F.J. Kelly	Under negotiation
Application of Centrax preparation on coprocessing slurries	Sandwell Beak Research Group	S. Fouda	In progress
Study to investigate furnace system design options, Phase IV	Consumer's Gas	A.C.S. Hayden	In progress
High efficiency oil-fired warm-air furnace and domestic water heater	Clare Brothers	A.C.S. Hayden	In progress

Contract Title	Contractor	Scientific Authority	Status
A retrofit package for gas-fired furnace, Phase III	Clare Brothers	A.C.S. Hayden	Under negotiation
Efficiency and emission of central wood-fired air furnaces		A.C.S. Hayden	In preparation
Pre-engineering assessment of lime kiln operation	Sandwell	A.C.S. Hayden	In progress
Enersolve demonstration project at sewage plant	BFH/Shawinigan	A.C.S. Hayden	In progress
Pre-engineering assessment of district heating system	Keen Eng.	A.C.S. Hayden	In progress
Enersolve demonstration at newsprint mill	SNC	A.C.S. Hayden	In progress
Pre-engineering assessment of acid plant	Fenco Lavalin	A.C.S. Hayden	Completed
Pre-engineering assessment of vegetable oil plant	Monenco	A.C.S. Hayden	In progress
Enersolve demonstration project of curing oven recuperator	Kent Eng.	A.C.S. Hayden	In progress
To update, produce and publish combustion handbooks for Canadian fuels	Canadian Inst. of Energy	A.C.S. Hayden	In progress
Evaluation of the potential for the application of flue gas condensing systems to industrial boilers	RFP	A.C.S. Hayden	Under negotiation
Characterization of coal surfaces by ion microprobe mass analyses - Phase II - Surface oxidation	University of Western Ontario	J.A. MacPhee	In progress
Rheology and rheological testing of Western Canadian bituminous coal, Phase II	Waterloo Centre for Process Development	J.T. Price	In progress
An investigation of the reactivity of inertines in Western Canadian coking coals	D.E. Pearson Assoc. Ltd.	J.T. Price	In progress
Development of a reflectogram-based coke strength prediction technique applicable to Western coals	D.E. Pearson Assoc. Ltd.	J.T. Price	Under negotiation

Contract Title	Contractor	Scientific Authority	Status
Ion microscope studies of the oxidation of coal on a microscope scale (SIMS) - Phase III	University of Western Ontario	J.A. MacPhee	Under negotiation
Beneficiation of low-rank Canadian coals with heavy residual, Phase III	Gulf Canada	D. Fung	In progress
Prediction of flow and temperature conditions in the CCRL drop furnace	University of Ottawa	P. Hughes	In progress
Performance prediction of the CCRL tunnel furnace for coal combustion	Imperial College of Science and Technology (UK)	H. Whaley	In progress
FTIR-PAS evaluation of combustion on behaviour of bituminous coals, Phase II	St. Francis Xavier University	J.A. MacPhee	In progress
Burner velocity profile measurement	University of Ottawa	P. Hughes	Completed
Scanning and transmission election microscope studies of macerals and pore structure in coals	ORF	K. Thambimuthu	In progress
Design and construction and commissioning of an apparatus for determination of sintering characteristics of coal ashes	RFP	K. Thambimuthu	Under negotiation
Beneficiation of low rank coal with heavy oil	Gulf Canada	D. Fung	Completed
The reduction of light oil usage in coal-fired fossil stations	Ontario Hydro	P. Hughes	Completed
Design of ARFC research facility	INTEG	D.L. Desai	Completed
Pilot plant studies of fluidized-bed combustion	Queen's University	E.J. Anthony	In progress
Combustion, sulphur neutralization and vanadium balance tests with Syncrude coke and limestone	RFP	D.L. Desai	Under negotiation
Develop a simulation model of the CFB Summerside project: ASPEN simulation	Queen's University	E.J. Anthony	In progress

Contract Title	Contractor	Scientific Authority	Status
Study on combustion of Suncor coke in a CFB	Technical University of Nova Scotia	E.J. Anthony	In progress
Coal plug feeding - mathematical model	Ecocel Ltd.	D.L. Desai	In progress
Coal tailings utilization study FB dryer and electrical co-generation	Luscar Ltd.	F. Friedrich	In progress
Participation in and reporting on a workshop on mechanical modelling of FBC	Queen's University	F. Friedrich	In progress
Determination of combustion and heat transfer parameters of a number of coal-water mixtures (CWM)	International Flame Research Foundation	H. Whaley	Completed
Determination of combustion and heat transfer parameters of the CBDC. Coal-water mixture compared to heavy oil fuel	Technical University of Nova Scotia	K. Thambimuthu	In progress
Coal-water slurry derating assessment for utility boiler No. 9 - Charlottetown	Babcock-Wilcox Canada	H. Whaley	Under negotiation
Testing of prototype burners - Chatham, N.B	New Brunswick Electric Power Commission	H. Whaley	In progress
Test of Western mining coal for coal-water mixture combustion	Westar Mining Ltd.	F. Friedrich	Under negotiation
An assessment of potential coal-water slurry atomizers and burners for application to industrial combustion systems in Canada	R. Grossman Consultants	H. Whaley	In progress
Industrial scale testing of coal-water slurries in a wet process cement kiln	Canada Cement Lafarge	H. Whaley	Under negotiation
Combustion and performance testing of a coal-water fuel at Chatham, N.B.	New Brunswick Electric Power Commission	H. Whaley	Under negotiation
Installation and evaluation of novel pulverized coal burners at CFB Gagetown	Volcano Inc.	G.K. Lee	In progress

Contract Title	Contractor	Scientific Authority	Status
To monitor performance testing for low N & S oxides retrofit burners at CFB, Gagetown	G.A. Robb Assoc.	G.K. Lee	In progress
Pre-heating of wood chips by simulated Kraft recovery flue gas	University of British Columbia	R.W. Braaten	Completed
Indirect combustion efficiency measurement at the Sherlton energy research facility	Technical University of Nova Scotia	R.W. Braaten	In progress
To evaluate and improve accuracy of efficiency and emission of central chunk wood-fired warm heating system	RFP	R.W. Braaten	Under negotiation
RESEARCH AGREEMENTS			
Methanation catalysis and higher alcohol synthesis	McMaster Univ.	J.F. Kriz	Completed
Microwave induced metal hydride catalytic hydrogenation and hydrocracking of bitumen	Queen's Univ.	J.F. Kriz	In progress
INDUSTRIAL RESEARCH ASSISTANCE PROGRAM			
Studies on commercial production of dimethyl formamide, methyl formate and formamide	Chinook Chemicals Co.	J.F. Kriz	Completed

COST RECOVERY WORK $\overset{)}{-}$ (NON-ROUTINE)

Job. No.	Company/Project	Cost ($K)	% Recovery
024330	New Brunswick Electric Power Commission Fuels Evaluation for province of New Brunswick	18	100%
024404	Cape Breton Development Corporation Combustion Evaluation of CBDC Metallurgical Grade Coal in a Pilot-Scale Utility Boiler.	13	67%
024406	Crows Nest Resources Ltd. Combustion Characteristics of Bryan Mountain Blend Coal	18	67%
024408	Crows Nest Resources Ltd. Combustion Evaluation of Telkwa Thermal Coal in a Pilot-Scale Utility Boiler	49.5	67%
024409	Westar Mining Ltd. Combustion Evaluation of Coal Creek in a Pilot-Scale Utility Boiler	51.5	67%
025400	Westar Mining Ltd. Combustion Evaluation of Natal Ridge Coal in a Pilot-Scale Utility Boiler	31	67%
024104	Canadian Carbonization Research Association		
	Research Investigations	99*	
	Confidential Oven Tests	118.7	100%
024401	Gulf Canada Resources Inc. - Goodrich Coal	18	67%

*per Agreement with CANMET

COST RECOVERY WORK - (ROUTINE - INCLUDES EXCHANGE ANALYSES)

Abitibi-Price
AMAX Coal Co.
Bioshell Plants:
  Lac Mégantic
  Hearst, Ont.
  Iroquois Falls
Canada Cement Lafarge
Canadian Interlaboratory Round Robin
Combustion Engineering Co.
Commercia Testing and Engineering
Department of National Defence - Coal evaluation; petroleum fuels analysis
Dofasco Inc.
Environment Canada - Coal evaluation
Environment Canada - Wastewater Technology Centre
Forintek Canada
Fuels and Lubricants Laboratory
Fuels Engineering of New York
Gossan Resources
National Research Council - Division of Mechanical Engineering
Ontario Ministry of Natural Resources - Petroleum
Others (DPW, Univ. of Ottawa, CCA, DVA, Private Companies)
Research Productivity Council
Resources Inspections
SGS Group
Standard Laboratories

TOTAL VALUE = $30K

APPENDIX E

CONTACTS, MEETINGS, FIELD TRIPS, AND JOINT CONSULTATIONS

CONTACTS, MEETINGS AND FIELD TRIPS

ERL continued its leadership role in research into fossil fuel technology, energy conversion and energy conservation. As a leading research organization it is necessary to maintain external contacts with other research organizations for technology transfer and exchange of information related to its research programs. In this connection the second CANMET Coal Conversion Contractors' Review Meeting was held in Calgary, November 14-16, 1984 to promote coordination, information exchange and technology transfer. More than 120 delegates from Canada, U.S., Japan and West Germany attended. A special session on coal and oil coprocessing was included. This session was timely because of the recent increase in interest in coprocessing worldwide, particularly in the U.S. Five sessions were held on: direct hydroliquefaction, international cooperation, pyrolysis/fundamentals, gasification and coprocessing of coals with bitumens and heavy oils.

In March 1985 two ERL scientists visited a number of coal liquefaction research establishments in Japan to become familiar with their latest research advances and how these impact current and future programs at CANMET, especially in coprocessing. A series of special lectures and presentations were made on the CANMET coal liquefaction and coprocessing research programs. The following government and industrial facilities were visited: AIST, MITI, Tokyo; NEDO, Sunshine City, Tokyo; Nippon Kokon Kabushiki, Technical Research Center, Kawasaki; Government Industrial Research Institute, Kyushu; the Research Institute for Industrial Science, Kyashu University, Fukuoka; Mitsubshi Heavy Industries Ltd., Hiroshima Technical Institute, Hiroshima; Kobe Steel Ltd., Kobe as R&D performer for the Nippon Brown Coal Liquefaction Co. Ltd.; National Research Institute for Pollution and Resources, Tsukba City; National Chemical Laboratory for Industry, Tsukba City; Mitsui Engineering and Shipbuilding Co. Ltd., Chiba Research Center, Chiba; Sumitomo Metal Co. Ltd., Hayaki Research Center, Hayaki; Government Industrial Development Laboratory, Sapporo; Coal Research Center, Hokkaido University, Sapporo. Also one of the two scientists was invited to attend the International Symposium on "Chemistry of Coal Liquefaction and Catalysis", March 17-20, Sapporo, Hokkaido.

In August 1984 one ERL scientist gave ten lectures in China and six presentations in Japan and Canada on flame measurements, modelling of furnace heat transfer, new combustion technology, acid rain emissions from fuel burning and design of pilot-scale combustion facilities.

ERL scientists were active in 54 conferences across the continent and in other parts of the world at a cost of approximately $63 000. A total of 66 technical papers were presented, 13 publications were contributed to learned journals as indicated in Appendix B and 54 confidential reports were prepared.

During 1984/85 ERL hosted visits by scientific and technical personnel from many parts of the world, as well as conducting numerous tours of its facilities.

The research agreements and contracts awarded to industry, private consultants, and universities continued to grow necessitating continued technical supervision and travel by staff. In addition to consultations related to the contracts in Appendix D of this report, many visits were made to discuss and evaluate new proposals or to make preliminary plans for contract work in the next fiscal year. The development of the CANMET shared-cost energy conversion program, for example, required extensive contact by ERL technical and scientific staff.

On an individual basis, ERL scientists engage in external consultations through their membership in technical committees as indicated in Appendix C. Substantial contributions were made to standardization organizations such as ISO, CSA, and ASTM. The committees of these organizations include representatives from public and private sectors as well as from academic institutions.

ERL remains in the forefront of energy research and cooperates with others through the exchange of information and granting programs to private industry and universities. The expenses incurred by staff members at the Bells Corners Complex in carrying out 330 field trips related to these activities approached $247 000.

JOINT PROVINCIAL/INDUSTRY/FEDERAL/INTERNATIONAL CONSULTATIONS

PROVINCIAL

Alberta Department of Economic Development
Alberta Department of Energy and Natural Resources
Alberta Research Council
Alberta Oil Sands Technology and Research Authority (AOSTRA)
Alberta Office of Coal Research
Association Candienne-français pour l'avancement des sciences (ACFAS)
B.C. Hydro, Vancouver
New Brunswick Electric Power Commission
New Brunswick Ministry of Fisheries and Oceans
Nova Scotia Power Corporation
Nova Scotia Research Foundation
Ontario Ministry of Energy
Saskatchewan Department of Energy and Mines
Saskatchewan Oil Research & Development
Saskatchewan Power Corporation
Saskatchewan Research Council
Supply and Services Canada
Workmen's Compensation Board, Alberta

INDUSTRY

Canada Cement Lafarge, Québec
Canada Packers
Canadian Boiler Society
Canadian Carbonization Research Association
Canadian Coal Liquefaction Corp., Edmonton
Canadian Combustion Research Association
Canadian Electrical Association, Montreal
Canadian Home Builders' Association
Canadian Methanol Canadien, Winnipeg
Canadian Standards Association
Canadian Utilities Limited
Canadian Western Natural Gas
Chemelectron Inc., Toronto
Coal Association of Canada
Combustion Engineering of Canada
Contar Systems Engineering Ltd., Edmonton
Crown Forest Products, Campbell River, B.C.
Dearborn Chemical, Hamilton
Denison Mines, Vancouver
Dow Corning, Toronto
Electric Appliance Manufacturers Association of Canada
Esso Resources, Calgary
Foster Wheeler Canada
Gas Intercité, Québec
Gulf Oil Research Laboratories, Sheridan Park
Gulf Resources, Calgary
Hatch Associates, Toronto
Husky Oil, Calgary
Industrial Energy Task Force, Ottawa
Iron Ore Company
Keen Engineering, Vancouver
Lamb-Cargate Inc., Vancouver
Luscar Limited, Edmonton
Manalta Coal Ltd., Calgary
McIntyre Mines, Calgary
Monserco Ltd., Toronto
Nimarec Engineering, Edmonton
Nova Corporation, Alberta
Nova-Husky Research Corporation, Calgary
Petro-Canada
Sandwell Beak Research Group, Mississauga, Ont.
Saskatchewan Minerals, Chaplin, Saskatchewan
Shannon & Assoc., Toronto
Sirman Associates, Markham, Ontario
Standards Council of Canada
Syncrude Corporation
Trans Alta Utilities Corporation, Calgary
Trans Canada Pipelines, Toronto
Underwood McClelland Associates Group
Vertec Combustion System Ltd., Alberta

INDUSTRY (cont'd)

Wade Engineering, Toronto
Waldman Associates, Winnipeg
Zenon Environmental Inc., Burlington

FEDERAL

Agriculture Canada
Consumer and Corporate Affairs Canada
Department of National Defence
Department of Regional Industrial Expansion
Environment Canada
Export Development Corporation
Health and Welfare Canada
Interdepartmental Committee on Fuels and Lubricants
Ministry of State for Science and Technology
Revenue Canada
Transport Canada

INTERNATIONAL

UNITED STATES

Air Projects and Chemicals Incorporated, Allentown, Pennsylvania
Alliance to Save Energy, Washington, D.C.
AMAX Coal Corporation, Evansville, Indiana
American Wildlife Federation, Washington, B.C.
Argonne National Laboratory, Illinois
Atlantic Research Group, Virginia
AVCO Everett Research Laboratories, Massachusetts
Battelle Columbus Laboratory, Ohio
Brookhaven National Laboratory
Electric Power Research Institute, Palo Alto, California
Florida Light and Power, St. Petersburg
Kerr-McGee Corporation, Oklahoma
Massachusetts Department of Energy
Minnesota Department of Energy
Minnesota Power Corporation
Pittsburgh Energy Technology Center
RAND Corporation, California
Rockwell Corporation, Los Angeles, California
Standard Laboratories, Charleston, West Virginia
Tennessee Valley Authority
U.S. Army Corps of Engineers
U.S. Department of Energy
U.S. Environmental Protection Agency
W.A.L. Incorporated, Denver, Colorado

OTHERS

BHARAT Heavy Electricals Ltd., India
Centre de recherche de Group Petrofina, Belgium
Danish Boiler Manufacturers Association, Copenhagen
Federal Government of Netherlands
Fuel Research Centre, Italy
Hydrocarbon Processing Research Group, Statoil, Stavenger, Norway
Indian Institute of Technology
TOTAL-Compagnie Française de Raffinage, France